

**Full Fuel Cycle Analysis  
of Biomass to Ethanol:  
Wastewater Treatment  
System Performance**

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## **Introduction**

### **Background**

The Department of Energy, through the National Renewable Energy Laboratory (NREL) has embarked upon a program to develop technologies for the production of fuel grade ethanol from renewable biomass resources. One of the current projects in the overall program is the Biomass-to-Ethanol Total Energy Cycle Analysis. The objective of this project is to characterize the economic and environmental consequences of some of the transportation fuel alternatives.

The project is evaluating ethanol production from six sources. Five of the sources are assumed to be crops grown specifically for ethanol production. The five crop sources have been selected based on the crops most likely to be grown in different regions of the country. The sixth source of biomass is the cellulytic fraction of municipal solid waste (MSW). It has been assumed for these evaluations that the process to produce ethanol from MSW will be ready by the year 2000, while the production from the other sources will begin in 2010.

An important part of the biomass-to-ethanol conversion process is the wastewater treatment system. The system must treat all wastewater streams from the process so that the effluent is suitable for discharge or reuse in the process. This report summarizes a study that evaluated wastewater treatment systems capable of treating the wastewater from biomass-to-ethanol production facilities. The selected treatment system, along with the sizing and cost of the system, is discussed first. A discussion of the potential inputs/outputs and environmental effects of the treatment system follows.

### **Objectives**

The objectives of the Wastewater Treatment System Performance Study were as follows:

- To define treatment systems potentially applicable for the wastewater from biomass-to-ethanol production facilities
- To provide preliminary sizing of the treatment systems
- To provide preliminary equipment lists and order-of-magnitude cost estimates for the proposed systems
- To estimate the inputs, outputs, and emissions resulting from system operation
- To provide qualitative and quantitative estimates of the environmental emissions and effects resulting from system operation

# Wastewater Characteristics and Discharge Criteria

## Wastewater Characteristics

Wastewater characteristics for the six waste streams were developed by NREL from mass balances on the ethanol production process. The mass balances were based on major components found in the biomass and ethanol production process. These components were converted to parameters more typically used for wastewater system design, including chemical oxygen demand (COD), biochemical oxygen demand (BOD), and total suspended solids (TSS). Appendix A provides the conversions used and the raw data tables. Table 1 summarizes of the major characteristics of the combined waste streams from the production facilities, not including the utility waste streams (cooling tower blowdown and steam system blowdown).

Table 1  
Wastewater Characteristic Summary

Case	Location	Flow (gpm)	COD (mg/l)	COD Load (lb/d)	Sulfate (mg/l)	TDS (mg/l)	TSS (mg/l)
1	Great Plains	153	140,000	257,000	602	7,200	470
2	Northeast	154	129,000	237,000	597	3,900	510
3	Southeast	160	119,000	228,000	617	3,300	560
4	Midwest/Lake St.	155	120,000	220,000	600	3,700	500
5	Pac. Northwest	158	72,000	138,000	589	2,300	680
6	MSW-Chicago	157	61,000	117,000	599	3,100	380

The COD concentration of these waste streams is very high; higher than has been reported in the literature for similar process. An attempt has been made in the design of the ethanol production process to minimize the use of water so that waste strengths at these levels may be expected. Much of the COD results from the presence of furfural (as much as 50 percent of the total). Although there may be ways to remove the furfural upstream in the production facility, this study did not consider that possibility. The high sulfate and total dissolved solids (TDS) concentrations in part result from the use of acid hydrolysis and lime for neutralization after hydrolysis. For this study, neutralization was assumed to occur in the production facility so the wastewater will have a pH of near neutral.

There will also be waste streams from "utilities" (for example, cooling tower blowdown and steam system blowdown). The volume of these streams was estimated from the utility sizing provided by NREL. These are rough estimates that assume the same makeup water quality for all six cases. The actual flows will depend on the inorganic quality of the water used as makeup. Table 2 summarizes the flows and the assumed TDS concentrations of the combined utility waste streams.

Table 2 Summary of Utility Waste Streams		
Case	Flow (gpm)	TDS (mg/l)
1	242	4,000
2	269	4,000
3	269	4,000
4	276	4,000
5	364	4,000
6	253	4,000

### Discharge Criteria

Discharge locations had to be assumed because sites for the ethanol production facilities have not yet been defined. For Case 6 (MSW-year 2000), the effluent was assumed to be discharged to a publicly owned treatment works (POTW) since the facility is likely to be near an urban area. POTWs often require that industrial wastewaters be treated to levels similar to municipal wastewater. Consequently, the following discharge criteria were selected:

- BOD: 300 mg/l
- TSS: 300 mg/l

A COD of 600 mg/l was used to size the treatment systems. This level of total organics may not be achievable, depending on the concentration of non-biodegradable organics in the wastewater and produced during treatment.

The ethanol production facilities for Cases 1 through 5 are likely to be near the land used to grow the biomass crops, and thus away from urban areas. Consequently, no POTW is likely to be close enough to accept the effluent. Land application of the effluent, along with the sludge, to the land used to grow the crops was selected as the disposal method. There are no set criteria for such disposal. In general, the effluent and the sludge should be biologically stable enough not to cause odors when they are applied. Achieving the same criteria as above for discharge to a POTW should produce a stable effluent.

# Wastewater System Description

## System Selection

Processes used for wastewater treatment are generally a function of the strength of the wastes. The strength of these wastewaters is in a range higher than that typically used for anaerobic biological treatment but lower than that for direct incineration in a boiler. Some type of concentration (for example, evaporation or ultrafiltration) would have to be used before incineration to reduce the amount of water sent to the boiler. The evaporation or ultrafiltration processes are both relatively costly and have other associated concerns. For example, extensive off-gas treatment would probably be required for the evaporation process. Ultrafiltration, a concentrating process using membranes, has been plagued by technical problems. It also produces a sidestream water that requires further treatment. However, during a more detailed analysis of wastewater treatment options, these alternatives should be considered further.

Although these waste strengths are higher than typical, they should be treatable using staged anaerobic/aerobic biological processes. As will be discussed below, although a large number of tanks will be required to achieve the treatment, the total cost should be similar or less than the concentration/incineration processes discussed above. Studies into the treatment of similar wastes have not found major problems with inhibition from the wastes. Recycling effluent may be required for most of the cases to dilute the waste to ensure that it is not inhibitory to the microbial activity. Mixing the utility waste streams with the process waste streams could also be used for dilution. Dilution with the utility streams will not significantly impact the sizing of the system or system emissions, so it was not considered this analysis.

## Process Description for Case 6

Figure 1 shows the processes selected for treatment of the wastewaters from Case 6 (MSW in the year 2000). The wastewater will be screened using a bar screen (1/2 inch spacing) as it leaves the ethanol production facility to remove any large solids that could cause mechanical problems. The wastewater will then flow to a flow-and-concentration equalization tank. Although the production process is likely to be relatively consistent, some variations will occur that will require organic concentration equalization. A 24-hour retention time was selected as a conservative estimate. Filtrate from sludge dewatering will be returned to the process at the equalization tank. The tank will be mixed using a mixer (side entry or submersible) to maintain a uniform wastewater concentration and temperature.

The equalized wastewater will be pumped through a heat exchanger to cool the wastewater to 55°C (the temperature required for thermophilic microbial activity) and into the anaerobic reactors. The heat exchanger will be a shell and tube type with the process water in the tube side. The heat exchanger cooling water blowdown could be used in the process plant, sent to the POTW for Case 6, or sent to land application for Cases 1 through 5.

Thermophilic anaerobic treatment is not commonly used because of the cost of heating the wastewater up to the thermophilic range. Because heating is not required here (the wastewater is already hot) and because thermophilic anaerobic treatment should result in higher reaction rates and thus, potentially smaller anaerobic reactors, thermophilic anaerobic treatment was selected. Completely mixed

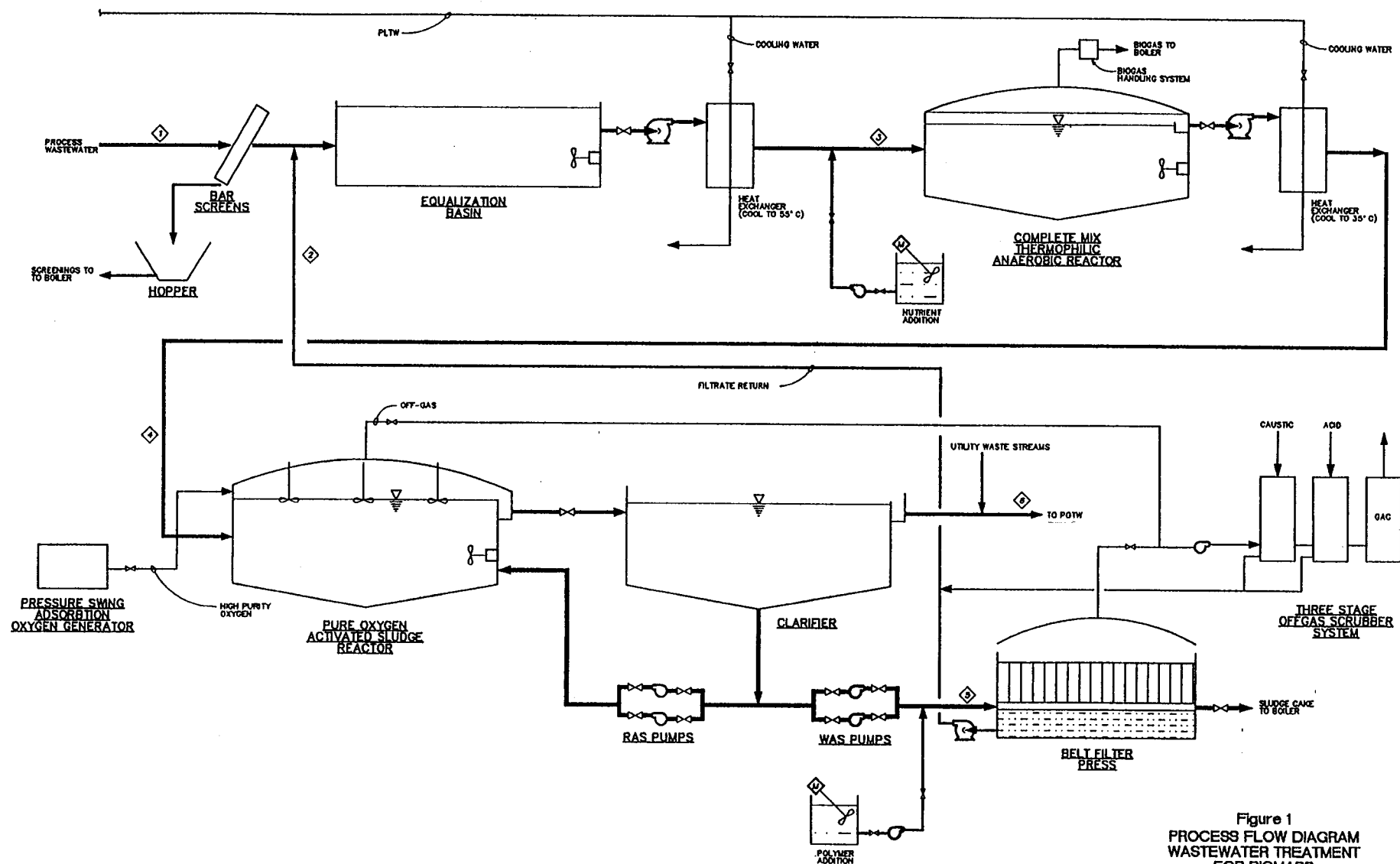


Figure 1  
PROCESS FLOW DIAGRAM  
WASTEWATER TREATMENT  
FOR BIOMASS  
TO ETHANOL FACILITY  
CASE 6

anaerobic reactors will be used. The concentration of sludge in such reactors is the same as that in the effluent (that is, it is not concentrated in any way). Because of the high wastewater strength, enough anaerobic organisms should grow each day to maintain a relatively high sludge concentration. Consequently, it is not necessary to have mechanisms or devices to concentrate the sludge in the reactor such as is done in fixed film reactor, upflow sludge blanket reactors, or solids contact reactors. The cost per gallon of capacity of completely mixed reactors is significantly less than that of other reactors with concentrating mechanisms. The anaerobic reactors will be mixed with mechanical mixers (side entry or submersible).

A nutrient solution will be pumped into the piping that feeds the anaerobic reactor. The composition of the nutrient solution will depend on what is locally available at the lowest cost. For example, urea and triple super phosphates are typically inexpensive forms of nitrogen and phosphorus.

Biogas from the anaerobic reactor will be fed to the boiler after it passes through a biogas system. The mass of sulfur in the gas should be relatively low compared to that in the other fuels feeding the boiler. Consequently, treatment of the gas to remove sulfur was assumed to not be necessary. The biogas system will include gas compressors, a sediment trap, a control system, and an emergency flare.

Effluent from the anaerobic reactor will be further cooled to between 30° and 35°C in a second shell and tube-type heat exchanger before it goes to the aerobic reactor. Although aerobic thermophilic processes can be used, they typically produce sludge with poor settling properties, which makes the operation of an activated sludge process difficult, or impossible. Consequently, a mesophilic activated sludge system was selected as the process of choice. Aerated lagoons can also be used if large amounts of land are available. The high strength of the wastewater, even after anaerobic treatment, makes the use of fixed-film systems impractical because the media could easily plug with biological growth.

With a desire to minimize emissions to the atmosphere, a pure oxygen activated sludge system was selected. A pure oxygen system will decrease both the quantity of gas requiring treatment and the mass of volatile compounds that are stripped. With the high strength waste, the cost of a pure oxygen system should be nearly identical to that of an air system, also making it economically feasible. For the mass of oxygen required, a pressure swing adsorption (PSA) system is the most economical. Surface mechanical aerators will provide mixing and oxygen transfer in the reactor. The activated sludge reactors will be compartmentalized—with the gas flowing through the reactor concurrently with the wastewater flow to maximize oxygen transfer to the water.

Effluent from the activated sludge reactors will flow by gravity to clarifiers, in which the sludge will be concentrated and separated from the clear liquid. Much of the sludge will be recycled back to the reactor (return activated sludge [RAS]) to increase the sludge concentration in the reactor. The excess sludge that is produced in both the anaerobic and the aerobic reactors will be wasted (waste activated sludge [WAS]) from the underflow of the clarifier. The utility waste streams will be mixed with the treated effluent, and both will be pumped to a POTW for final treatment before discharge to a receiving stream. The utility waste streams should not require treatment, because they are only likely to contain dissolved solids that should not impact the POTW.

The WAS will be dewatered using a belt filter press. Polymer will be added to the sludge to aid the dewatering process. Sludge cake will be sent to the boilers to be burned. The belt press will be operated for 12 hours per day.



Off gas from the activated sludge reactor and from a hood over the belt filter press will be sent to a scrubber system to remove odors and volatile compounds. The scrubber system will include an acid mist scrubber to remove ammonia and other caustic compounds, a caustic mist scrubber to remove hydrogen sulfide and other acidic compounds, and a activated carbon column to remove any organics that should get through the mist scrubbers. This is a conservative system that may not be necessary in its entirety. A less costly system may be suitable if air emissions are low and if they are not a regulatory or health concern.

### Process Description for Cases 1 to 5

Although the waste strengths of the five cases vary somewhat, one common process was developed for use in all cases. The size of the systems will differ for most of the cases.

The process train selected for Cases 1 through 5 is similar to that for Case 6. Figure 2 presents a process flow diagram for the Case 1-5 system. The following are the differences between the two systems:

- Effluent from the activated sludge clarifier will be recycled to the equalization tank to dilute the waste water. Recycle rates were selected to produce COD concentrations of about 60,000 mg/l (similar to that of Case 6).
- Both the sludge and the effluent will be land applied. POTWs will not likely be near the ethanol production facilities to accept the effluent so the effluent must be either land applied or discharged to a surface water. Large quantities of land that the biomass crops are grown on should be available for land application. Sludge application to the land that the biomass crops are grown on is also suggested. The organic matter and nutrients in the sludge will serve as soil enhancers.

The nitrogen uptake of the biomass crops controls the amount of land required for land application. No more nitrogen can be added to the land than is taken up by the crops. A high of 9,200 acres to a low of 5,000 acres is estimated to be needed to balance the nitrogen uptake of the crops to that applied in sludge.

The high TDS content of the wastewater and the utility stream will require that the effluent be diluted (or blended) with low TDS water as it is applied or soon after it is applied. The high TDS of the effluents could injure the crops if it is not diluted. The ratio of blend water to wastewater is quite high; as high as 6:1. This translates to 5 to 8 inches per year of total water be applied to the crop land used for land application. During rainy periods, rain water could provide the required dilution. Cooling water from the heat exchangers could also be used for dilution. If this much water is not available, would not be otherwise applied for irrigation, or does not fall as rain, land application may not be viable.

The salts in the water will also have to be leached from the soil to avoid salt buildup. This will require the addition of low TDS irrigation water (or rain) and that the soils be well drained. If they do not drain, a drainage system may be required.

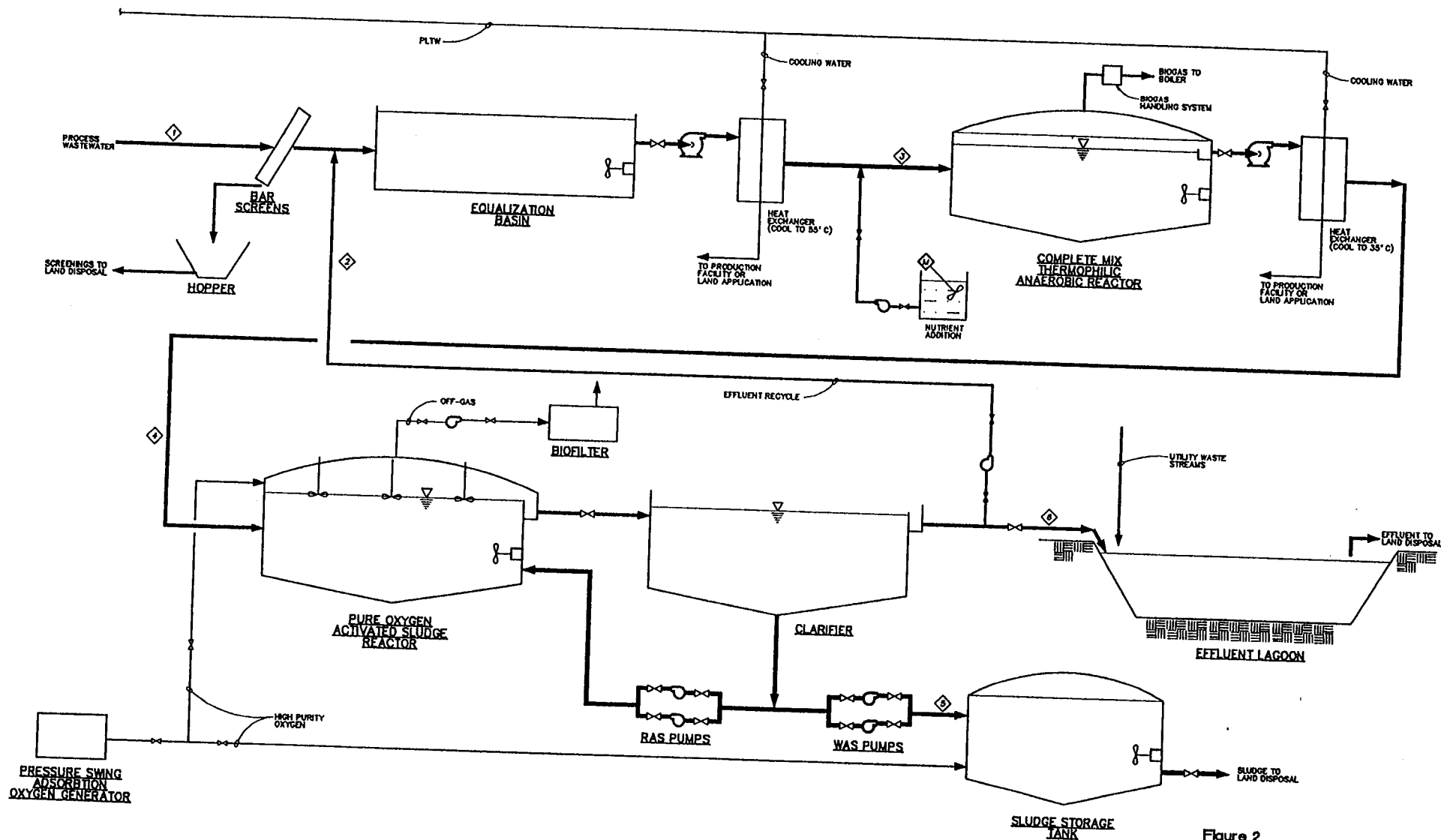


Figure 2  
PROCESS FLOW DIAGRAM  
WASTEWATER TREATMENT  
FOR BIOMASS  
TO ETHANOL FACILITY  
CASES 1-5

In many parts of the country, there will be at least 3 months out of each year that effluent and sludge cannot be land applied because of frozen ground or excess rainfall. Consequently, a storage lagoon from 18 to 22 acres in area will be provided to store the effluent and sludge.

The suitability of land application depends on the rainfall patterns of the site location, the soil type, and the background water quality. Consequently, the applicability will have to be more closely studied once sites are selected.

- The off gas from the activated sludge reactor will be passed through a biofilter rather than scrubbers. Biofilters are piles of composted manure and/or other organic material that can adsorb the volatile compounds, which allows microorganisms the time to degrade the volatile compounds. After the useful life of the biofilter material, it can be applied to crop land as a soil enhancer. Although only currently used in a few installations for odor control, biofilters also show promise for removing many volatile organic compounds.

## **Wastewater System Sizing**

Appendix B contains a design summary for the systems selected for each alternative. Sizing criteria are also provided. In general, conservative design assumptions and simplified design procedures were used for this sizing. More detailed design procedures should be used once the nature of the wastewater and the site constraints are better defined. The procedures used should not impact the definition of the system emissions, although they may result in cost estimates that are somewhat higher than actual costs will be.

## Wastewater System Cost Estimate

Capital cost estimates were prepared for each case by obtaining budget prices for major pieces of equipment from equipment vendors or from estimates of similar projects. A factor was added to the cost of each piece of equipment to account for installation. Other factors were added to account for general requirements, instrumentation, and mechanical and electrical items. Estimates for buildings were based on the square footage of the facility and on the type of facility. The cost of sitework was based on the overall area of the site for each case. A contingency of 30 percent was added to the bottom line of each estimate, which is typical for an "order of magnitude" estimate.

These cost estimates can be considered "order-of-magnitude" estimates based on definitions of the American Association of Cost Engineers. The accuracy of the estimates is plus 50 percent, minus 30 percent. These cost estimates have been prepared for guidance in project evaluation from the information available at the time the estimates were prepared. The final cost of the project will depend on the final project scope, actual labor and material costs, competitive market conditions, the implementation schedule, and other variable factors as they occur. As a result, the final project cost will vary from the estimates presented herein.

The cost estimates presented here are based on 1991 dollars and construction of the facilities in the Denver area. Estimates of costs in other locations can be prepared by adjusting these costs by using the *Engineering News-Record* Construction Cost Index (ENR CCI) for each city.

Operations and maintenance (O&M) costs were prepared covering major items including labor, utilities, chemicals, and maintenance. The NREL provided the unit costs for many of the items.

Table 3 provides a summary of the capital and O&M cost estimates; details of the cost estimates can be found in Appendix D. Also included in Appendix D is a list of assumptions used to prepare the cost estimates.

Case	Total Capital Costs (\$)	Total O&M Costs (\$/year)
1	22,800,000	3,120,000
2	22,000,000	2,980,000
3	19,910,000	2,780,000
4	19,910,000	2,760,000
5	14,700,000	2,010,000
6	11,400,000	1,970,000

## Mass Balance of Inputs and Outputs

Major inputs and outputs/emissions of the wastewater treatments systems for all cases, along with approximate estimates of the mass of each, are provided in Table 4. A detailed mass balance of the wastewater system for COD and TSS is provided in Appendix C. Minor outputs/emissions are discussed in the following section.

The resin in the PSA oxygen generation unit will require replacement after a number of years. The mass of the resin was considered too small to take into account here. Likewise, the activated carbon in the off-gas scrubber of Case 1 will have to be replaced at some time. The life of the carbon will likely be long since the two-stage mist scrubber located upstream of the carbon will remove much of the hydrogen sulfide and organics in the off gas.

**Table 4**  
**Summary of Inputs and Outputs**

	Case					
	1	2	3	4	5	6
<b>Inputs</b>						
Process Wastewater (Mill lb/d)	2.00	2.00	2.06	2.00	1.99	1.96
Utility Waste Water (Mill lb/d)	2.91	3.23	3.23	3.31	4.37	3.04
Blend Water for Land Application (Mill lb/d)	30.5	23.8	22.0	23.3	5.13	—
Urea (lb/d)	8,400	7,800	7,450	7,300	4,400	3,700
Triple Super Phosphate (lb/d)	3,300	3,000	2,900	2,800	1,700	1,500
Cooling Water (Mill lb/d)	7.6	7.6	7.6	7.6	5.7	5.7
Manure (lb/d)	83.8	77.8	74.5	72.8	44.3	—
Acid for Off-gas Scrubber (lb/d)	—	—	—	—	—	12
Caustic for Off-gas Scrubber (lb/d)	—	—	—	—	—	12
Polymer (lb/d)	—	—	—	—	—	31.8
<b>Outputs/Emissions</b>						
Combined Effluent to POTW (Mill lbs/d)	—	—	—	—	—	5.0
Combined Effluent to Land Application (Mill lb/d)	4.91	5.23	5.29	5.31	6.36	—
Blend or Cooling Water to Land Application (Mill lb/d)	30.5	23.8	22.0	23.3	5.13	—
Sludge to Boiler (dry lb/d)	—	—	—	—	—	6,360
Sludge to Land Application (dry lb/d)	14,200	13,200	12,700	12,400	7,580	—
Screenings to Boiler (lb/d)	small quantities	small quantities	small quantities	small quantities	small quantities	small quantities
Heat Exchanger Blowdown (Mill lb/d)	7.6	7.6	7.6	7.6	5.7	5.7
Methane to Boiler (lb/d)	62,000	57,500	55,100	53,800	32,900	27,700
Carbon Dioxide to Boiler (lb/d)	41,300	38,300	36,700	35,900	21,900	18,500
Hydrogen Sulfide to Boiler (lb/d)	277	276	296	279	279	282
Carbon Dioxide from Activated Sludge (lb/d)	47,500	44,100	42,200	41,200	25,200	21,300
"Spent" Biofilter Material (lb/d)	83.8	77.8	74.5	72.8	44.3	—

## Environmental Emissions and Effects

Table 5 summarizes the environmental emissions and concerns directly from the biomass to ethanol wastewater treatment system. This table follows the format of Figure 1 of the Statement of Work. Emissions indirectly from the wastewater system, such as from the burning of the biogas in the boiler, are not discussed here. More detailed discussion of the emissions and concerns follows.

### Air Releases

Emissions to the air of criteria pollutants and toxics should be minimal or non-exist from this wastewater system. The biogas from the anaerobic system will contain some pollutants that will be destroyed in the boiler when the biogas is burned. Although the boiler may emit criteria pollutants (for example, sulfur dioxide) from biogas combustion, emissions from the boiler are outside the scope of this study.

Volatilization of organics formed in the anaerobic reactor (for example, acetic acid) could potentially occur in the aerobic reactor. However, most of these compounds are biodegradable under aerobic conditions, so that they will be degraded before they can be volatilized. Reducing the gas flow in the reactor by using pure oxygen will favor degradation overstripping. Any compounds that are stripped will be removed from the gas stream in either the off-gas scrubbers or in the biofilter.

Carbon dioxide will be emitted from the wastewater system. Table 4 provides estimates of the emissions rates.

Air toxics are not expected to be emitted from the wastewater system because they are not present in the wastewater, and they will not be formed in the treatment process. The one possible exception to this is Case 6, with MSW as the biomass feed stock. MSW may contain volatile organics from household hazardous wastes. If these volatiles are not removed in the ethanol production facilities, they may make it into the wastewater stream and be stripped in the anaerobic or aerobic reactors. However, much of what is stripped from the reactors will be removed from the gas stream or destroyed in the gaseous treatment process (the boiler, off-gas scrubbers, or the biofilter). Consequently, even if volatile organic compounds reach the wastewater treatment system, few will be emitted to the atmosphere.

The gas from the aerobic activated sludge system is likely to be at water temperature (35°C) so it can be elevated relative to ambient temperatures. Some heat will also be emitted from the tanks.

### Water Releases

For Case 6, effluent will be indirectly released to a surface water. The release will be indirect, because the effluent will be sent to a POTW for further treatment. The effluent from the POTW will discharge water with a probable suspended solids content of 30 mg/l or less. Consequently, the suspended solids contributed by the ethanol production wastewater would be at most 57 lb/d. The POTW effluent should contain little or no oil and grease or priority pollutants that were contributed by the ethanol production wastewater. The ethanol production wastewater may contain a small



**Table 5**  
**Summary of Environmental Emissions and Concerns**  
**from the Wastewater Treatment System**

Parameter	Quantitative	Qualitative
<b><i>Air Releases</i></b>		
Sulfur Dioxide	None directly	
Nitrogen Oxide	None directly	
Carbon Monoxide	None directly	
PM-10	None directly	
Lead	None directly	
VOC-total	Minimal or none	
VOC-breakdown	Minimal or none	
Carbon Dioxide	see Table 4	
CH <sub>4</sub>	None (sent to boiler)	
Acetaldehyde	None expected	
Formaldehyde	None expected	
Other Toxics		None expected
Radionuclides		None
Thermal		See text
<b><i>Water Releases</i></b>		
Suspended Solids	Case 6 only: 57 lb/d at POTW discharge	
Oil and Grease		Little or none
Priority Pollutants		Little or none
Thermal	430 Mill Btu/day	
<b><i>Land Concerns</i></b>		
Land Area	Cases 1-4-28 acres Case 5-38 acres Case 6-8 acres	
Erosion	Minimal additional	
<b><i>Other Concerns</i></b>		
Health/Safety		No additional concern
Noise		No additional concern
Odors		No additional concern
Catastrophic Events		No additional concern
Aesthetics		See text

amount of color that should not be an environmental problem for the discharge of the wastewater. The ethanol production wastewater will have an elevated temperature (about 30°C) by the time it reaches the POTW. Depending on the total flow of the POTW, this increased temperature may or may not raise the temperature of the POTW effluent. The heat value listed in Table 4 assumes that the wastewater will be discharged at a temperature of 30°C and that no cooling occurs in the POTW.

For Cases 1-5, there will be no direct discharge to a surface water because the effluent will be land applied. With proper design and operation, there should be minimal runoff of the effluent to surface waters.

## **Land Concerns**

The wastewater treatment system will require approximately 8 to 12 acres of land to contain all of the tanks needed. An approximate footprint for the wastewater systems was developed by assuming 2-million-gallon tanks, 20 feet deep (see Table 5). The values listed for cases 1 through 5 include land for an effluent storage lagoon.

Some erosion is likely to occur during the construction of the wastewater treatment systems. With good construction practices, erosion should be minimal or typical of a construction project. Once this facility is completed, there will be little or no erosion if land is properly landscaped.

Some erosion may occur from the land application of the effluent and sludge for Cases 1-5. With a proper design and good management practices, minimal erosion should take place.

As discussed above, the land application of the effluent and sludge will add TDS and nitrogen to the soil. The TDS content of the applied water will have to be diluted as it is applied (or soon thereafter) to avoid salt toxicity to the plants. Low TDS water will also have to be applied or come from rain fall to avoid TDS build up. The TDS may be leached into the groundwater where it should not result in an environmental problem unless there is little dilution in the groundwater system and the groundwater is used for drinking or irrigation. The nitrogen in the sludge could leach from the soil into the groundwater if the application rates are not controlled to match the uptake by the crops.

## **Other Concerns**

The wastewater treatment system should impose minimal additional health and safety concerns over that of the ethanol production facility. Standard health and safety design consideration and operational practices will have to be followed for the wastewater system. Prime areas of concern include the biogas handling system, the pure oxygen system, and any confined spaces.

Some noise could be released from the wastewater treatment system. Most of the noise will come from blowers and pumps. Methods are available to effectively control the noise if it is a concern at the location of the production facilities. Thus, it can be assumed that methods will be employed so that no additional noise will be released from the wastewater treatment facilities.

With proper design and operations, odors should not be released from the wastewater system. The design discussed above includes the use of off-gas treatment methods that will effectively control odors from the wastewater system.

The wastewater system should not increase the risk of a catastrophic event. No facility or activity in the system can cause a catastrophic event. Although health and safety concerns exist, they do not have the capability of causing a catastrophic event.

The wastewater system will impact the aesthetics of the area of the facilities, because the system will change the native land use. The aesthetic impacts will vary, depending on the amount of money that is spent to minimize the impacts. For the capital cost included here, conventional efforts were assumed for improving the aesthetics of the site. Thus, even though the site will visually look like a wastewater treatment facility, through landscaping and appropriate architectural design of buildings, it will look acceptable to the average person.

# **Appendix A**

## **Wastewater Characterization**

Environmental Analysis For The Utility Systems in The Biomass - To - Ethanol Process  
Material Balance For The Waste Water Treatment System

\*\* NOTE : NREL PROTECTED INFORMATION \*\*

05-Dec-91 CDW, DEN32922.A0  
SERITABL.WK1

Calculations: 1. See notes by CDW dated 10-21-91 for conversion factor notes as shown here -

Component	TSS	Conversion Factor (mg/mg)			TDS
		COD	BOD	SO4	
S. SOLIDS		2.47	1.12		
ASH					1
LIGNIN	1				
PROTEIN		1.7	0.4		
XYLOSE		1.07			
HMF		1.67	0.77		

Component	TSS	Conversion Factor (mg/mg)			TDS
		COD	BOD	SO4	
FURFURAL		1.67	0.77		
GYPSUM(S)				0.58	1
GYPSUM	1			0.58	
CELLULASE		1.7	0.4		
GLYCEROL		1.22			
CELL MASS		1.42			

2. Flow, gpm = Water Loading (lb/hr) \* (1.998 E-3)

3. Component concentration, mg/l = Loading (lb/hr) \* Conversion Factor (mg/mg) \* 7575.76 ((mg/min)/(lb/hr))/ Flow (gpm)/ 3.785 (l/gal)

note : for eqn. #3, 7575.76/3.785 = 2001.52 was used in the spreadsheet.

4. TDS and TSS are fixed solids which are not biodegradable

5. TDS only includes inorganic solids

## ETHANOL TO BIOMASS WASTEWATER CHARACTERIZATION

\*\* NOTE : NREL PROTECTED INFORMATION \*\*

CASE 1: GREAT PLAINS, 2010

		WATER	SOLUBLE SOLIDS	ASH	LIGNIN	CRUDE PROTEIN	XYLOSE	HMF	FURFURAL	GYPSUM (SOL)	GYPSUM (INSOL)	CELLULAS	GLYCEROL	CELL MASS	TOTAL	FLOW gpm
STRM.NO.1	LB/HR	33534	1149	474	28	275	163	0	23	74	8	16	782	5	36540	67
PROCESS WATER TO	TSS,mg/l				836						239				1075	
WASTE TREATMENT	COD,mg/l		84781			13966	4891	0	1147			762	27771	212	133529	
	BOD,mg/l		38443			3286		0	529			179			42437	
	SO4,mg/l									1238	134				1372	
	TDS,mg/l			14160						2211					16370	
STRM.NO.2	LB/HR	42514	0	0	0	0	0	0	3720	0	0	0	0	0	48234	85
OFFGAS FROM	TSS,mg/l				0				312-11		0				0	
BLOWDOWN TANK	COD,mg/l		0			0	0	0	146383	11245		0	0	0	146343	
	BOD,mg/l		0			0		0	67494			0			67494	
	SO4,mg/l									0	0				0	
	TDS,mg/l			0						0					0	
STRM.NO.3	LB/HR	320	0	0	0	0	0	0	0	0	0	0	0	0	320	1
WASTE WATER	TSS,mg/l				0						0				0	
FROM CIP/CS	COD,mg/l		0			0	0	0	0			0	0	0	0	
	BOD,mg/l		0			0		0	0			0			0	
	SO4,mg/l									0	0				0	
	TDS,mg/l			0						0					0	
STRM.NO.4	LB/HR	76368	1149	474	28	275	153	23	3720	74	8	16	782	5	83054	153
STREAM TO	TSS,mg/l				387				630-11		105				472	
ANAEROBIC DIGESTION	COD,mg/l		37228			6132	2147	504	81482			334	12185	93	140126	
	BOD,mg/l		16661			1443		232	37674			79			56259	
	SO4,mg/l									544	59				652	
	TDS,mg/l			6218						971					7188	

612  
61 - 313,500

FEED

1,395 gpm

612 - 1,791 gpm = 302 gpm

## CASE 2: NORTHEAST, 2010

		SOLUBLE				CRUDE					GYPSUM	GYPSUM		CELL		FLOW
		WATER	SOLIDS	ASH	LIGNIN	PROTEIN	XYLOSE	HMF	FURFURAL	(SOL)	(INSOL)	CELLULAS	GLYCEROL	MASS	TOTAL	gpm
STRM.NO.1 PROCESS WATER TO WASTE TREATMENT	LB/HR	33943	1025	227	32	223	128	25	0	75	7	14	793	5	36497	68
	TSS,mg/l				944						207				1151	
	COD,mg/l		74720			11188	4042	1232	0			702	28553	210	120847	
	BOD,mg/l		33881			2633		568	0			165			37247	
	SO4,mg/l									1240	116				1355	
	TDS,mg/l			6699						2213					8913	
STRM.NO.2 OFFGAS FROM BLOWDOWN TANK	LB/HR	42775	0	0	0	0	0	0	3469	0	0	0	0	0	46244	85
	TSS,mg/l				0						0				0	
	COD,mg/l		0			0	0	0	135874			0	0	0	135874	
	BOD,mg/l		0			0		0	62556			0			62556	
	SO4,mg/l									0	0				0	
	TDS,mg/l			0						0					0	
STRM.NO.3 WASTE WATER FROM CIP/CS	LB/HR	320	0	0	0	0	0	0	0	0	0	0	0	0	320	1
	TSS,mg/l				0						0				0	
	COD,mg/l		0			0	0	0	0			0	0	0	0	
	BOD,mg/l		0			0		0	0			0			0	
	SO4,mg/l									0	0				0	
	TDS,mg/l			0						0					0	
STRM.NO.4 STREAM TO ANAEROBIC DIGESTION	LB/HR	77038	1028	227	32	223	128	25	3469	75	7	14	793	5	83082	154
	TSS,mg/l				416						91				507	
	COD,mg/l		32954			4930	1781	543	75332			309	12580	92	128521	
	BOD,mg/l		14943			1160		250	34734			73			51160	
	SO4,mg/l									546	51				597	
	TDS,mg/l			2952						975					3927	

## CASE 3: SOUTHEAST, 2010

		SOLUBLE			CRUDE					GYPSUM	GYPSUM			CELL		FLOW
		WATER	SOLIDS	ASH	LIGNIN	PROTEIN	XYLOSE	HMF	FURFURAL	(SOL)	(INSOL)	CELLULAS	GLYCEROL	MASS	TOTAL	gpm
STRM.NO.1 PROCESS WATER TO WASTE TREATMENT	LB/HR	36507	759	191	38	162	139	25	0	81	7	15	847	5	38776	73
	TSS,mg/l				1043						192				1235	
	COD,mg/l		51443			7557	4081	1146	0			700	28355	195	93477	
	BOD,mg/l		23326			1778		528	0			165			25797	
	SO4,mg/l									1245	108				1352	
	TDS,mg/l			5241						2223					7464	
STRM.NO.2 OFFGAS FROM BLOWDOWN TANK	LB/HR	43054	0	0	0	0	0	0	3627	0	0	0	0	0	46881	86
	TSS,mg/l				0						0				0	
	COD,mg/l		0			0	0	0	140934			0	0	0	140934	
	BOD,mg/l		0			0		0	64981			0			64981	
	SO4,mg/l									0	0				0	
	TDS,mg/l			0						0					0	
STRM.NO.3 WASTE WATER FROM CIP/CS	LB/HR	320	0	0	0	0	0	0	0	0	0	0	0	0	320	1
	TSS,mg/l				0						0				0	
	COD,mg/l		0			0	0	0	0			0	0	0	0	
	BOD,mg/l		0			0		0	0			0			0	
	SO4,mg/l									0	0				0	
	TDS,mg/l			0						0					0	
STRM.NO.4 STREAM TO ANAEROBIC DIGESTION	LB/HR	79981	759	181	38	162	139	25	3627	81	7	15	847	5	85867	160
	TSS,mg/l				476						88				564	
	COD,mg/l		23481			3448	1863	523	75865			319	12943	89	118532	
	BOD,mg/l		10647			812		241	34980			75			46755	
	SO4,mg/l									568	49				617	
	TDS,mg/l			2267						1015					3282	



## CASE 4: MIDWEST/LAKE STATES, 2010

		SOLUBLE		ASH	LIGNIN	CRUDE		HMF	FURFURAL	GYPSUM (SOL)	GYPSUM (INSOL)	CELLULAS	GLYCEROL	CELL MASS	TOTAL	FLOW gpm
		WATER	SOLIDS			PROTEIN	XYLOSE									
STRM.NO.1 PROCESS WATER TO WASTE TREATMENT	LB/HR	34272	924	207	32	232	116	23	0	76	7	14	784	5	36692	68
	TSS,mg/l				935						205				1140	
	COD,mg/l		66710			11528	3628	1123	0			696	27958	208	111850	
	BOD,mg/l		30249			2713		518	0			164			33643	
	SO4,mg/l									1244	115				1359	
	TDS,mg/l			6051						2221					8272	
STRM.NO.2 OFFGAS FROM BLOWDOWN TANK	LB/HR	43027	0	0	0	0	0	0	3274	0	0	0	0	0	46301	86
	TSS,mg/l				0						0				0	
	COD,mg/l		0			0	0	0	127297			0	0	0	127297	
	BOD,mg/l		0			0		0	58694			0			58694	
	SO4,mg/l									0	0				0	
	TDS,mg/l			0						0					0	
STRM.NO.3 WASTE WATER FROM CIP/CS	LB/HR	320	0	0	0	0	0	0	0	0	0	0	0	0	320	1
	TSS,mg/l				0						0				0	
	COD,mg/l		0			0	0	0	0			0	0	0	0	
	BOD,mg/l		0			0		0	0			0			0	
	SO4,mg/l									0	0				0	
	TDS,mg/l			0						0					0	
STRM.NO.4 STREAM TO ANAEROBIC DIGESTION	LB/HR	77619	924	207	32	232	116	23	3274	76	7	14	784	5	83313	165
	TSS,mg/l				413						90				503	
	COD,mg/l		29455			5090	1602	496	70565			307	12344	92	119952	
	BOD,mg/l		13356			1198		229	32536			72			47391	
	SO4,mg/l									549	51				600	
	TDS,mg/l			2672						981					3652	

## CASE 5: PACIFIC NORTHWEST, 2010

		SOLUBLE		ASH	LIGNIN	CRUDE				GYPSUM (SOL)	GYPSUM (INSOL)	CELLULAS	GLYCEROL	CELL MASS	TOTAL	FLOW gpm
		WATER	SOLIDS			PROTEIN	XYLOSE	HMF	FURFURAL							
STRM.NO.1 PROCESS WATER TO WASTE TREATMENT	LB/HR	35044	280	101	49	37	62	24	0	78	5	13	802	4	36499	70
	TSS,mg/l				1401						143				1544	
	COD,mg/l		19770			1798	1898	1146	0			632	27970	162	53374	
	BOD,mg/l		8965			423		528	0			149			10064	
	SO4,mg/l									1249	80				1329	
STRM.NO.2 OFFGAS FROM BLOWDOWN TANK	TDS,mg/l			2887						2230					5117	
	LB/HR	43633	0	0	0	0	0	0	2284	0	0	0	0	0	45917	87
	TSS,mg/l				0						0				0	
	COD,mg/l		0			0	0	0	87571			0	0	0	87571	
	BOD,mg/l		0			0		0	40377			0			40377	
STRM.NO.3 WASTE WATER FROM CIP/CS	SO4,mg/l									0	0				0	
	TDS,mg/l			0						0					0	
	LB/HR	320	0	0	0	0	0	0	0	0	0	0	0	0	320	1
	TSS,mg/l				0						0				0	
	COD,mg/l		0			0	0	0	0			0	0	0	0	
STRM.NO.4 STREAM TO ANAEROBIC DIGESTION	BOD,mg/l		0			0		0	0			0			0	
	SO4,mg/l									0	0				0	
	TDS,mg/l			0						0					0	
	LB/HR	78997	280	101	49	37	62	24	2284	78	5	13	802	4	82736	158
	TSS,mg/l				621						63				685	
	COD,mg/l		8770			798	841	508	48369			280	12408	72	72046	
	BOD,mg/l		3977			188		234	22302			66			28767	
	SO4,mg/l									554	36				589	
	TDS,mg/l			1281						989					2270	

## CASE 6: MUN. SOLID WASTE, 2000

		SOLUBLE			CRUDE					GYPSUM	GYPSUM		CELL			
		WATER	SOLIDS	ASH	LIGNIN	PROTEIN	XYLOSE	HMF	FURFURAL	(SOL)	(INSOL)	CELLULAS	GLYCEROL	MASS	TOTAL	FLOW
																gpm
STRM.NO.1	LB/HR	34478	667	166	23	169	33	24	0	77	7	17	835	5	36501	69
PROCESS WATER TO	TSS,mg/l				668						203				872	
WASTE TREATMENT	COD,mg/l		47868			8348	1026	1165	0			840	29598	206	89050	
	BOD,mg/l		21705			1964		537	0			198			24404	
	SO4,mg/l									1253	114				1367	
	TDS,mg/l			4823						2237					7060	
STRM.NO.2	LB/HR	43810	0	0	0	0	0	0	1034	0	0	0	0	0	44844	88
OFFGAS FROM	TSS,mg/l				0						0				0	
BLOWDOWN TANK	COD,mg/l		0			0	0	0	39485			0	0	0	39485	
	BOD,mg/l		0			0		0	18205			0			18205	
	SO4,mg/l									0	0				0	
	TDS,mg/l			0						0					0	
STRM.NO.3	LB/HR	320	0	0	0	0	0	0	0	0	0	0	0	0	320	1
WASTE WATER	TSS,mg/l				0						0				0	
FROM CIP/CS	COD,mg/l		0			0	0	0	0			0	0	0	0	
	BOD,mg/l		0			0		0	0			0			0	
	SO4,mg/l									0	0				0	
	TDS,mg/l			0						0					0	
STRM.NO.4	LB/HR	78608	667	166	23	169	33	24	1034	77	7	17	835	5	81665	157
STREAM TO	TSS,mg/l				293						89				382	
ANAEROBIC DIGESTION	COD,mg/l		20995			3661	450	511	22006			368	12982	90	61064	
	BOD,mg/l		9520			861		236	10146			87			20850	
	SO4,mg/l									550	50				599	
	TDS,mg/l			2115						981					3097	

## **Appendix B**

### **Design Summary**

**APPENDIX B**  
**DESIGN SUMMARY**

**CASE 1**  
**GREAT PLAINS, 2010**

Bar Screens

Number: Two  
Type: Mechanically Cleaned  
Bar Spacing: 1/2 inch

Equalization Tank

Number: One  
Type: Above grade, welded steel  
Volume: 225,000 gal  
Size: 45 ft diam, 20 ft SWD  
Hydraulic Retention Time: 24 hours  
Mixers: 3, side entry, 4 hp (based on 30 hp/mg)

Primary Heat Exchanger Influent Pump

Number: Two (one redundant)  
Type: Centrifugal, variable speed drive  
Capacity: 400 gpm at 15 ft total head

Primary Heat Exchanger

Number: One  
Type: Shell and tube type, process water in tube  
Surface Area: 131 sq ft  
Temperature Reduction: 142 degrees F to 131 degrees F  
Cooling Water Required: 46.5 gpm

Nutrient Feed System

Number: One  
Type: Dry or liquid  
Capacity: 8,300 lb/d urea and 3,300 lb triple super phosphate

Anaerobic Reactor

Number: Six  
Type: Above grade, welded steel with cover  
Volume: 2.0 mill gal  
Size: 130 ft diam, 20 ft SWD  
Organic Loading Rate: 2.5 kg/d/cu m  
Mixers: Four, side entry, 20 hp (based on 40 hp/mg)

#### Secondary Heat Exchanger Influent Pump

Number: Two (one redundant)  
Type: Centrifugal, variable speed drive  
Capacity: 400 gpm at 15 ft total head

#### Secondary Heat Exchanger

Number: One  
Type: Shell and tube type, process water in tube  
Surface Area: 366 sq ft  
Temperature Reduction: 131 degrees F to 86 degrees F  
Cooling Water Required: 587 gpm

#### Aeration Tanks

Number: Five  
Type: Above grade, concrete, covered  
Volume: 0.675 mill gal  
Size: 40 ft wide by 150 ft long, 15 ft SWD  
Solids Retention Time: 20 days  
Mixers: Four per tank, surface, 15 hp (based on 4 lb O<sub>2</sub>/hp-hr transfer)

#### Pressure Swing Adsorption Oxygen Generator

Number: One  
Capacity: 18 tons per day

#### Clarifier

Number: Two  
Type: Flocculating center well with positive sludge drawoff  
Size: 30 ft diam, 15 ft SWD  
Solids Loading Rate: 20 lb/d/sq ft

#### Return Activated Sludge Pumps

Number: Two (one redundant)

Type: Centrifugal, solids handling, variable speed  
Capacity: 400 gpm at 20 ft total head

#### Waste Activated Sludge Pumps

Number: Two (one redundant)  
Type: Centrifugal, solids handling, variable speed  
Capacity: 150 gpm at 20 ft total head

#### Sludge Storage Tank

Number: One  
Type: Above grade, welded steel  
Volume: 850,000 gal  
Size: 85 ft diam, 20 ft SWD  
Days of Storage: 5  
Mixers: Four, side entry, 10 hp (based on 40 hp/mg), supply a small amount of pure oxygen to keep aerobic

#### Biofilter

Number: One  
Type: Composted manure and other organic material  
Volume: 38 cu yds (31 tons) (based on 1 cfm/sq ft, 8 ft high)

#### Effluent Storage Lagoon

Number: One  
Type: Lined, open  
Criteria: Store Process WW and Utility WW for 3 months  
Depth: 10 water depth  
Area: 18 acre

#### Land Application

Area Required: 9,000 ac (based on 9 months of application), 1.1 in/yr over this area  
Assumed Required Conductivity: 1.1 mmhos/cm  
Assumed Crop Uptake: 200 lbs-N/ac  
Blend Water Requirements: 2,500 gpm (7.1 in/yr over above area)  
Leach Water: 1.2 in/yr (if applied over the above area)  
Application Equipment: provided elsewhere

## DESIGN SUMMARY

### CASE 2 NORTHEAST, 2010

#### Bar Screens

Number: Two  
Type: Mechanically Cleaned  
Bar Spacing: 1/2 inch

#### Equalization Tank

Number: One  
Type: Above grade, welded steel  
Volume: 225,000 gal  
Size: 45 ft diam, 20 ft SWD  
Hydraulic Retention Time: 24 hours  
Mixers: 3, side entry, 4 hp (based on 30 hp/mg)

#### Primary Heat Exchanger Influent Pump

Number: Two (one redundant)  
Type: Centrifugal, variable speed drive  
Capacity: 400 gpm at 15 ft total head

#### Primary Heat Exchanger

Number: One  
Type: Shell and tube type, process water in tube  
Surface Area: 131 sq ft  
Temperature Reduction: 142 degrees F to 131 degrees F  
Cooling Water Required: 46.5 gpm

#### Nutrient Feed System

Number: One  
Type: Dry or liquid  
Capacity: 7,800 lb/d urea and 3,000 lb triple super phosphate

#### Anaerobic Reactor

Number: Six  
Type: Above grade, welded steel with cover



Volume: 2.0 mill gal  
Size: 130 ft diam, 20 ft SWD  
Organic Loading Rate: 2.5 kg/d/cu m  
Mixers: Four, side entry, 20 hp (based on 40 hp/mg)

#### Secondary Heat Exchanger Influent Pump

Number: Two (one redundant)  
Type: Centrifugal, variable speed drive  
Capacity: 400 gpm at 15 ft total head

#### Secondary Heat Exchanger

Number: One  
Type: Shell and tube type, process water in tube  
Surface Area: 366 sq ft  
Temperature Reduction: 131 degrees F to 86 degrees F  
Cooling Water Required: 587 gpm

#### Aeration Tanks

Number: Five  
Type: Above grade, concrete, covered  
Volume: 0.675 mill gal  
Size: 40 ft wide by 150 ft long, 15 ft SWD  
Solids Retention Time: 20 days  
Mixers: Four per tank, surface, 15 hp (based on 4 lb O<sub>2</sub>/hp-hr transfer)

#### Pressure Swing Adsorption Oxygen Generator

Number: One  
Capacity: 16 tons per day

#### Clarifier

Number: Two  
Type: Flocculating center well with positive sludge drawoff  
Size: 30 ft diam, 15 ft SWD  
Solids Loading Rate: 20 lb/d/sq ft

#### Return Activated Sludge Pumps

Number: Two (one redundant)  
Type: Centrifugal, solids handling, variable speed  
Capacity: 400 gpm at 20 ft total head

### Waste Activated Sludge Pumps

Number: Two (one redundant)  
Type: Centrifugal, solids handling, variable speed  
Capacity: 150 gpm at 20 ft static head

### Sludge Storage Tank

Number: One  
Type: Above grade, welded steel  
Volume: 850,000 gal  
Size: 85 ft diam, 20 ft SWD  
Days of Storage: 5  
Mixers: Four, side entry, 10 hp (based on 40 hp/mg), supply a small amount of pure oxygen to keep aerobic

### Biofilter

Number: One  
Type: Composted manure and other organic material  
Volume: 35 cu yds (28 tons) (based on 1 cfm/sq ft, 8 ft high)

### Effluent Storage Lagoon

Number: One  
Type: Lined, open  
Criteria: Store Process WW and Utility WW for 3 months  
Depth: 10 water depth  
Area: 18 acre

### Land Application

Area Required: 8,500 ac (based on 9 months of application), 1.3 in/yr over this area  
Assumed Required Conductivity: 1.1 mmhos/cm  
Assumed Crop Uptake: 200 lbs-N/ac  
Blend Water Requirements: 2,000 gpm (6.0 in/yr over above area)  
Leach Water: 1.1 in/yr (if applied over the above area)  
Application Equipment: provided elsewhere

## DESIGN SUMMARY

### CASE 3 SOUTHEAST, 2010

#### Bar Screens

Number: Two  
Type: Mechanically Cleaned  
Bar Spacing: 1/2 inch

#### Equalization Tank

Number: One  
Type: Above grade, welded steel  
Volume: 225,000 gal  
Size: 45 ft diam, 20 ft SWD  
Hydraulic Retention Time: 24 hours  
Mixers: 3, side entry, 4 hp (based on 30 hp/mg)

#### Primary Heat Exchanger Influent Pump

Number: Two (one redundant)  
Type: Centrifugal, variable speed drive  
Capacity: 400 gpm at 15 ft total head

#### Primary Heat Exchanger

Number: One  
Type: Shell and tube type, process water in tube  
Surface Area: 131 sq ft  
Temperature Reduction: 142 degrees F to 131 degrees F  
Cooling Water Required: 46.5 gpm

#### Nutrient Feed System

Number: One  
Type: Dry or liquid  
Capacity: 7,500 lb/d urea and 3,000 lb triple super phosphate

#### Anaerobic Reactor

Number: Five  
Type: Above grade, welded steel with cover

Volume: 2.0 mill gal  
Size: 130 ft diam, 20 ft SWD  
Organic Loading Rate: 2.5 kg/d/cu m  
Mixers: Four, side entry, 20 hp (based on 40 hp/mg)

#### Secondary Heat Exchanger Influent Pump

Number: Two (one redundant)  
Type: Centrifugal, variable speed drive  
Capacity: 400 gpm at 15 ft total head

#### Secondary Heat Exchanger

Number: One  
Type: Shell and tube type, process water in tube  
Surface Area: 366 sq ft  
Temperature Reduction: 131 degrees F to 86 degrees F  
Cooling Water Required: 587 gpm

#### Aeration Tanks

Number: Four  
Type: Above grade, concrete, covered  
Volume: 0.675 mill gal  
Size: 40 ft wide by 150 ft long, 15 ft SWD  
Solids Retention Time: 20 days  
Mixers: Four per tank, surface, 15 hp (based on 4 lb O<sub>2</sub>/hp-hr transfer)

#### Pressure Swing Adsorption Oxygen Generator

Number: One  
Capacity: 15 tons per day

#### Clarifier

Number: Two  
Type: Flocculating center well with positive sludge drawoff  
Size: 30 ft diam, 15 ft SWD  
Solids Loading Rate: 20 lb/d/sq ft

#### Return Activated Sludge Pumps

Number: Two (one redundant)  
Type: Centrifugal, solids handling, variable speed  
Capacity: 400 gpm at 20 ft total head

### Waste Activated Sludge Pumps

Number: Two (one redundant)  
Type: Centrifugal, solids handling, variable speed  
Capacity: 150 gpm at 20 ft total head

### Sludge Storage Tank

Number: One  
Type: Above grade, welded steel  
Volume: 850,000 gal  
Size: 85 ft diam, 20 ft SWD  
Days of Storage: 5  
Mixers: Four, side entry, 10 hp (based on 40 hp/mg), supply a small amount of pure oxygen to keep aerobic

### Biofilter

Number: One  
Type: Composted manure and other organic material  
Volume: 34 cu yds (27 tons) (based on 1 cfm/sq ft, 8 ft high)

### Effluent Storage Lagoon

Number: One  
Type: Lined, open  
Criteria: Store Process WW and Utility WW for 3 months  
Depth: 10 water depth  
Area: 18 acre

### Land Application

Area Required: 8,300 ac (based on 9 months of application), 1.3 in/yr over this area  
Assumed Required Conductivity: 1.1 mmhos/cm  
Assumed Crop Uptake: 200 lbs-N/ac  
Blend Water Requirements: 1,800 gpm (5.7 in/yr over above area)  
Leach Water: 1.0 in/yr (if applied over the above area)  
Application Equipment: provided elsewhere

**DESIGN SUMMARY**  
**CASE 4**  
**MIDWEST/LAKES STATES, 2010**

Bar Screens

Number: Two  
Type: Mechanically Cleaned  
Bar Spacing: 1/2 inch

Equalization Tank

Number: One  
Type: Above grade, welded steel  
Volume: 225,000 gal  
Size: 45 ft diam, 20 ft SWD  
Hydraulic Retention Time: 24 hours  
Mixers: 3, side entry, 4 hp (based on 30 hp/mg)

Primary Heat Exchanger Influent Pump

Number: Two (one redundant)  
Type: Centrifugal, variable speed drive  
Capacity: 400 gpm at 15 ft total head

Primary Heat Exchanger

Number: One  
Type: Shell and tube type, process water in tube  
Surface Area: 131 sq ft  
Temperature Reduction: 142 degrees F to 131 degrees F  
Cooling Water Required: 46.5 gpm

Nutrient Feed System

Number: One  
Type: Dry or liquid  
Capacity: 7,300 lb/d urea and 2,800 lb triple super phosphate

Anaerobic Reactor

Number: Five  
Type: Above grade, welded steel with cover

Volume: 2.0 mill gal  
Size: 130 ft diam, 20 ft SWD  
Organic Loading Rate: 2.5 kg/d/cu m  
Mixers: Four, side entry, 20 hp (based on 40 hp/mg)

#### Secondary Heat Exchanger Influent Pump

Number: Two (one redundant)  
Type: Centrifugal, variable speed drive  
Capacity: 400 gpm at 15 ft total head

#### Secondary Heat Exchanger

Number: One  
Type: Shell and tube type, process water in tube  
Surface Area: 366 sq ft  
Temperature Reduction: 131 degrees F to 86 degrees F  
Cooling Water Required: 587 gpm

#### Aeration Tanks

Number: Four  
Type: Above grade, concrete, covered  
Volume: 0.675 mill gal  
Size: 40 ft wide by 150 ft long, 15 ft SWD  
Solids Retention Time: 20 days  
Mixers: Four per tank, surface, 15 hp (based on 4 lb O<sub>2</sub>/hp-hr transfer)

#### Pressure Swing Adsorption Oxygen Generator

Number: One  
Capacity: 15 tons per day

#### Clarifier

Number: Two  
Type: Flocculating center well with positive sludge drawoff  
Size: 30 ft diam, 15 ft SWD  
Solids Loading Rate: 20 lb/d/sq ft

#### Return Activated Sludge Pumps

Number: Two (one redundant)  
Type: Centrifugal, solids handling, variable speed  
Capacity: 400 gpm at 20 ft total head

### Waste Activated Sludge Pumps

Number: Two (one redundant)

Type: Centrifugal, solids handling, variable speed

Capacity: 150 gpm at 20 ft total head

### Sludge Storage Tank

Number: One

Type: Above grade, welded steel

Volume: 850,000 gal

Size: 85 ft diam, 20 ft SWD

Days of Storage: 5

Mixers: Four, side entry, 10 hp (based on 40 hp/mg), supply a small amount of pure oxygen to keep aerobic

### Biofilter

Number: One

Type: Composted manure and other organic material

Volume: 33 cu yds (27 tons) (based on 1 cfm/sq ft, 8 ft high)

### Effluent Storage Lagoon

Number: One

Type: Lined, open

Criteria: Store Process WW and Utility WW for 3 months

Depth: 10 water depth

Area: 18 acre

### Land Application

Area Required: 8,000 ac (based on 9 months of application), 1.3 in/yr over this area

Assumed Required Conductivity: 1.1 mmhos/cm

Assumed Crop Uptake: 200 lbs-N/ac

Blend Water Requirements: 1,900 gpm (6.2 in/yr over above area)

Leach Water: 1.1 in/yr (if applied over the above area)

Application Equipment: provided elsewhere



**DESIGN SUMMARY**  
**CASE 5**  
**PACIFIC NORTHWEST, 2010**

**Bar Screens**

Number: Two  
Type: Mechanically Cleaned  
Bar Spacing: 1/2 inch

**Equalization Tank**

Number: One  
Type: Above grade, welded steel  
Volume: 225,000 gal  
Size: 45 ft diam, 20 ft SWD  
Hydraulic Retention Time: 24 hours  
Mixers: 3, side entry, 4 hp (based on 30 hp/mg)

**Primary Heat Exchanger Influent Pump**

Number: Two (one redundant)  
Type: Centrifugal, variable speed drive  
Capacity: 400 gpm at 15 ft total head

**Primary Heat Exchanger**

Number: One  
Type: Shell and tube type, process water in tube  
Surface Area: 131 sq ft  
Temperature Reduction: 142 degrees F to 131 degrees F  
Cooling Water Required: 46.5 gpm

**Nutrient Feed System**

Number: One  
Type: Dry or liquid  
Capacity: 4,500 lb/d urea and 1,700 lb triple super phosphate

**Anaerobic Reactor**

Number: Three  
Type: Above grade, welded steel with cover

Volume: 2.0 mill gal  
Size: 130 ft diam, 20 ft SWD  
Organic Loading Rate: 2.5 kg/d/cu m  
Mixers: Four, side entry, 20 hp (based on 40 hp/mg)

#### Secondary Heat Exchanger Influent Pump

Number: Two (one redundant)  
Type: Centrifugal, variable speed drive  
Capacity: 400 gpm at 15 ft total head

#### Secondary Heat Exchanger

Number: One  
Type: Shell and tube type, process water in tube  
Surface Area: 366 sq ft  
Temperature Reduction: 131 degrees F to 86 degrees F  
Cooling Water Required: 587 gpm

#### Aeration Tanks

Number: Three  
Type: Above grade, concrete, covered  
Volume: 0.675 mill gal  
Size: 40 ft wide by 150 ft long, 15 ft SWD  
Solids Retention Time: 20 days  
Mixers: Four per tank, surface, 15 hp (based on 4 lb O<sub>2</sub>/hp-hr transfer)

#### Pressure Swing Adsorption Oxygen Generator

Number: One  
Capacity: 9 tons per day

#### Clarifier

Number: Two  
Type: Flocculating center well with positive sludge drawoff  
Size: 30 ft diam, 15 ft SWD  
Solids Loading Rate: 20 lb/d/sq ft

#### Return Activated Sludge Pumps

Number: Two (one redundant)  
Type: Centrifugal, solids handling, variable speed  
Capacity: 400 gpm at 20 ft total head

### Waste Activated Sludge Pumps

Number: Two (one redundant)  
Type: Centrifugal, solids handling, variable speed  
Capacity: 150 gpm at 20 ft total head

### Sludge Storage Tank

Number: One  
Type: Above grade, welded steel  
Volume: 850,000 gal  
Size: 60 ft diam, 20 ft SWD  
Days of Storage: 5  
Mixers: Four, side entry, 10 hp (based on 40 hp/mg), supply a small amount of pure oxygen to keep aerobic

### Biofilter

Number: One  
Type: Composted manure and other organic material  
Volume: 20 cu yds (16 tons) (based on 1 cfm/sq ft, 8 ft high)

### Effluent Storage Lagoon

Number: One  
Type: Lined, open  
Criteria: Store Process WW and Utility WW for 3 months  
Depth: 10 water depth  
Area: 22 acre

### Land Application

Area Required: 3,700 ac (based on 9 months of application), 2.8 in/yr over this area  
Assumed Required Conductivity: 3 mmhos/cm (for Poplars)  
Assumed Crop Uptake: 200 lbs-N/ac  
Blend Water Requirements: 427 gpm (2.2 in/yr over above area)  
Leach Water: 0.8 in/yr (if applied over the above area)  
Application Equipment: provided elsewhere

## DESIGN SUMMARY

### CASE 6 MSW, YEAR 2000

#### Bar Screens

Number: Two  
Type: Mechanically Cleaned  
Bar Spacing: 1/2 inch

#### Equalization Tank

Number: One  
Type: Above grade, welded steel  
Volume: 225,000 gal  
Size: 45 ft diam, 20 ft SWD  
Hydraulic Retention Time: 24 hours  
Mixers: 3, side entry, 4 hp (based on 30 hp/mg)

#### Primary Heat Exchanger Influent Pump

Number: Two (one redundant)  
Type: Centrifugal, variable speed drive  
Capacity: 400 gpm at 15 ft total head

#### Primary Heat Exchanger

Number: One  
Type: Shell and tube type, process water in tube  
Surface Area: 221 sq ft  
Temperature Reduction: 182 degrees F to 131 degrees F  
Cooling Water Required: 136 gpm

#### Nutrient Feed System

Number: One  
Type: Dry or liquid  
Capacity: 3,800 lb/d urea and 1,500 lb triple super phosphate

#### Anaerobic Reactor

Number: Three  
Type: Above grade, welded steel with cover

Volume: 2.0 mill gal  
Size: 130 ft diam, 20 ft SWD  
Organic Loading Rate: 2.5 kg/d/cu m  
Mixers: Four, side entry, 20 hp (based on 40 hp/mg)

#### Secondary Heat Exchanger Influent Pump

Number: Two (one redundant)  
Type: Centrifugal, variable speed drive  
Capacity: 400 gpm at 15 ft total head

#### Secondary Heat Exchanger

Number: One  
Type: Shell and tube type, process water in tube  
Surface Area: 336 sq ft  
Temperature Reduction: 131 degrees F to 86 degrees F  
Cooling Water Required: 338 gpm

#### Aeration Tanks

Number: Two  
Type: Above grade, concrete, covered  
Volume: 0.675 mill gal  
Size: 40 ft wide by 150 ft long, 15 ft SWD  
Solids Retention Time: 20 days  
Mixers: Four per tank, surface, 15 hp (based on 4 lb O<sub>2</sub>/hp-hr transfer)

#### Pressure Swing Adsorption Oxygen Generator

Number: One  
Capacity: 8 tons per day

#### Clarifier

Number: Two  
Type: Flocculating center well with positive sludge drawoff  
Size: 20 ft diam, 15 ft SWD  
Solids Loading Rate: 20 lb/d/sq ft

#### Return Activated Sludge Pumps

Number: Two (one redundant)  
Type: Centrifugal, solids handling, variable speed  
Capacity: 400 gpm at 20 ft total head

### Waste Activated Sludge Pumps

Number: Two (one redundant)

Type: Centrifugal, solids handling, variable speed

Capacity: 100 gpm at 20 ft total head

### Belt Filter Press

Number: One

Size: One meter press

Filtrate/Wash Recycle Pump: 200 gpm, centrifugal at 20 ft head

Polymer Feed System: Liquid feed, 32 lbs/d

Off-gas: 6460 cfm (based on 100 ft/m face velocity in a 2 m by 3 m hood)

### Off-Gas Scrubber System

Type: Two stage

First Stage: Caustic and hypochlorite mist scrubber

Size: 21 ft high, 10 ft diam.

Chemical Usage: 2 gal/hr of 12% NaOCl and 0.1 gal/hr NaOH

Second Stage: Granular Activated Carbon

Size: 10 ft diameter

## **Appendix C**

### **Mass Balance**

MASS BALANCE SPREADSHEET - SERI BIOMASS TO ETHANOL WWTP  
CDW, DEN32922.A0, MASSBAL.WK1 10-25-91

FOLLOWING IS A MASS BALANCE FOR THE WWT PROCESS IN TERMS  
OF COD, TSS, AND WATER FLOW

STREAM 1: PROCESS WASTEWATER

	FLOW	TSS IN		COD IN	
	gpm	lb/d	mg/l	lb/d	mg/l
CASE 1	153	868	472	257,476	140,126
CASE 2	154	938	507	237,698	128,521
CASE 3	160	1,083	564	227,764	118,532
CASE 4	155	937	503	223,289	119,952
CASE 5	158	1,299	685	136,709	72,046
CASE 6	157	721	382	115,136	61,064

STREAM 2: RECYCLES

	FLOW	TSS IN		COD IN	
	gpm	lb/d	mg/l	lb/d	mg/l
CASE 1	199	1,194	500	1,433	600
CASE 2	169	1,017	500	1,221	600
CASE 3	160	961	500	1,153	600
CASE 4	155	931	500	1,117	600
CASE 5	32	190	500	228	600
CASE 6	180	432	200	1,297	600

STREAM 3: ANAEROBIC REACTOR INFLUENT

	FLOW	TSS IN		COD IN	
	gpm	lb/d	mg/l	lb/d	mg/l
CASE 1	352	2,062	488	258,910	61,261
CASE 2	323	1,955	503	238,918	61,513
CASE 3	320	2,044	532	228,917	59,564
CASE 4	310	1,868	502	224,406	60,274
CASE 5	190	1,489	654	136,936	60,136
CASE 6	337	1,153	285	116,433	28,768

STREAM 4: AEROBIC REACTOR INFLUENT

	FLOW	TSS OUT		COD OUT	
	gpm	lb/d	mg/l	lb/d	mg/l
CASE 1	352	18,373	4,347	40,571	9,600
CASE 2	323	17,007	4,379	37,438	9,639
CASE 3	320	16,466	4,284	35,871	9,334
CASE 4	310	16,005	4,299	35,164	9,445
CASE 5	190	10,116	4,443	21,458	9,423
CASE 6	337	8,488	2,097	18,245	4,508



# STREAM 5: WASTE SLUDGE

			SOLUBLE				
			FLOW	TSS OUT	COD OUT		
			gpm	lb/d	mg/l	lb/d	mg/l
GP	CASE 1	119	14,231	10,000		854	600
NE	CASE 2	110	13,151	10,000		789	600
SE	CASE 3	106	12,730	10,000		764	600
MWLS	CASE 4	104	12,430	10,000		746	600
PNW	CASE 5	63	7,566	10,000		454	600
MSW	CASE 6	53	6,365	10,000		382	600

# STREAM 6: EFFLUENT (INCLUDING UTILITY WATER)

FLOW gpm	TSS OUT		COD OUT	
	lb/d	mg/l	lb/d	mg/l
475	2,855	500	3,426	600
503	3,020	500	3,624	600
503	3,021	500	3,625	600
483	2,897	500	3,477	600
491	2,946	500	3,535	600
500	3,870	600	3,603	600

## **Appendix D**

### **Cost Estimates**

12/09/91

FILE: SERI

CH2M HILL

WASTEWATER TREATMENT FOR ETHANOL FACILITY

PROJECT NO: DEM32922.A0

PREPARED BY: E.R. MEYER

WASTEWATER TREATMENT FOR ETHANOL FACILITY

SUMMARY OF COSTS

=====	
CASE	TOTAL COST
=====	
CASE 1	\$22,832,422
CASE 2	\$22,019,922
CASE 3	\$19,909,834
CASE 4	\$19,909,833
CASE 5	\$14,671,925
CASE 6	\$11,389,682

12/09/91

FILE: SERI

CH2M HILL

WASTEWATER TREATMENT FOR ETHANOL FACILITY

PROJECT NO: 06N32922.A0

PREPARED BY: E.R. MEYER

## WASTEWATER TREATMENT FOR ETHANOL FACILITY

DESCRIPTION	QUANT	UNIT	\$/UNIT	TOTAL COST	REFERENCE
<b>CASE 4</b>					
<b>GENERAL REQUIREMENTS:</b>					
General Requirements	6.00%		\$8,761,294	\$525,678	
<b>SITework:</b>					
Clear & Grub	6 ACRES		\$2,000.00	\$16,000	
<b>CLARIFIER STRUCTURE (20'D, 15' SWD):</b>					
<b>Earthwork:</b>					
Excavation	1,068 CY		\$3.00	\$3,203	
Structural Backfill	23 CY		\$10.00	\$233	
Backfill	807 CY		\$2.00	\$1,613	
<b>Concrete:</b>					
12" Slab on Grade	23 CY		\$200.00	\$4,652	
12" Walls	79 CY		\$400.00	\$31,633	
<b>Metals:</b>					
	1 LS		\$5,000.00	\$5,000	
<b>AERATION TANKS (40'X150'X17'H, ABOVE GRADE):</b>					
<b>Concrete:</b>					
12" Slab on Grade	444 CY		\$200.00	\$88,889	
12" Walls	351 CY		\$400.00	\$220,296	
<b>Metals:</b>					
	1 LS		\$5,000.00	\$5,000	
<b>BUILDINGS:</b>					
Office/Lab	2,100 SF		\$100.00	\$210,000	
Preliminary Treatment Building	900 SF		\$75.00	\$67,500	
Pump Building	1,200 SF		\$75.00	\$90,000	
Belt Filter Press Building	2,000 SF		\$75.00	\$150,000	
<b>EQUIPMENT</b>					
Bar Screens	1 EA		\$55,900.00	\$55,900	
Equalization Tank (Steel, 45'D, 20' SWD, 225,000 gal)	1 EA		\$126,000.00	\$126,000	91 MEANS 132-051-1000 * 1.2
Equalization Tank Mixers (3.2 HP)	3 EA		\$9,360.00	\$28,080	
Primary Heat Exchanger Influent Pump (400 gpm)	2 EA		\$5,590.00	\$11,180	
Primary Heat Exchanger	1 EA		\$12,181.00	\$12,181	
Nutrient Feed System	1 EA		\$23,400.00	\$23,400	
Anaerobic Reactor (2 Million Gallon)	3 EA		\$624,000.00	\$1,872,000	91 MEANS 132-051-1300 * 1.2

12/09/91

FILE: SERI

CH2M HILL

WASTEWATER TREATMENT FOR ETHANOL FACILITY

PROJECT NO: DEN32922.A0

PREPARED BY: E.A.MEYER

WASTEWATER TREATMENT FOR ETHANOL FACILITY

DESCRIPTION	QUANT	UNIT	\$/UNIT	TOTAL COST	REFERENCE
Biogas System	1	EA	\$144,000.00	\$144,000	
Anerobic Mixers (20 HP)	12	EA	\$22,555.00	\$270,660	
Secondary Heat Exchanger Influent Pump	2	EA	\$5,575.00	\$11,150	
Secondary Heat Exchanger	1	EA	\$18,948.30	\$18,949	
O2 Generation & Mixing System	1	LS	\$1,600,000	\$1,600,000	← + surface mixer
Clarifier Mechanism	2	EA	\$50,000.00	\$100,000	
WAS Pumps (4000 gpm)	2	EA	\$137,850.00	\$277,680	
WAS Pumps	2	EA	\$7,800.00	\$15,600	
Belt Filter Press	1	EA	\$192,000.00	\$192,000	
Carbon Scrubber System	1	EA	\$36,400.00	\$36,400	
Wast System & Backup Carbon	1	EA	\$168,000.00	\$168,000	
INSTRUMENTATION					
Allowance for Instrumentation	5.00%		\$8,761,294	\$438,065	
MECHANICAL					
Allowance for Mechanical	15.00%		\$8,761,294	\$1,314,194	
ELECTRICAL					
Allowance for Electrical	10.00%		\$8,761,294	\$876,129	
SUBTOTAL				\$8,761,294	
CONTINGENCY	30.00%		\$8,761,294	\$2,628,388	
TOTAL - CASE 6				\$11,389,682	

NOTE: Unit costs include the cost of installation.

12/09/91

FILE: SERI

CHZN HILL

WASTEWATER TREATMENT FOR ETHANOL FACILITY

PROJECT NO: DEM32922.AG

PREPARED BY: E.R.MEYER

WASTEWATER TREATMENT FOR ETHANOL FACILITY

DESCRIPTION	QUANT	UNIT	\$/UNIT	TOTAL COST	REFERENCE
<b>CASE 1</b>					
<b>GENERAL REQUIREMENTS:</b>					
General Requirements	6.00%		\$17,563,401	\$1,053,304	
<b>SITEWORK:</b>					
Clear & Grub	9 ACRES		\$2,000.00	\$18,000	
Effluent Storage Lagoon (18 Acres):					
Embankment	66,987 CY		\$10.00	\$669,867	91 MEANS 022-282-0100
HDPE Liner (20 mil)	104,564 SY		\$2.50	\$261,411	
<b>CLARIFIER STRUCTURE (20'D, 15' SWD):</b>					
Earthwork:					
Excavation	1,048 CY		\$3.00	\$3,203	
Structural Backfill	23 CY		\$10.00	\$233	
Backfill	807 CY		\$2.00	\$1,613	
Concrete:					
12" Slab on Grade	23 CY		\$200.00	\$4,632	
12" Walls	79 CY		\$400.00	\$31,633	
Metals:	1 LS		\$5,000.00	\$5,000	
<b>AERATION TANKS (40'X150'X17'H, ABOVE GRADE):</b>					
Concrete:					
12" Slab on Grade	1,111 CY		\$200.00	\$222,222	
12" Walls	1,152 CY		\$400.00	\$460,741	
Metals:	1 LS		\$5,000.00	\$5,000	
<b>BUILDINGS:</b>					
Office/Lab	2,100 SF		\$100.00	\$210,000	
Preliminary Treatment Building	900 SF		\$75.00	\$67,500	
Pump Building	1,200 SF		\$75.00	\$90,000	
Belt Filter Press Building	2,000 SF		\$75.00	\$150,000	
<b>EQUIPMENT</b>					
Bar Screens	1 EA		\$55,900.00	\$55,900	
Equalization Tank (Steel, 45'D, 20' SWD, 225,000 gal)	1 EA		\$126,000.00	\$126,000	91 MEANS 132-051-1000 * 1.2
Equalization Tank Mixers (3.2 HP)	3 EA		\$9,360.00	\$28,080	
Primary Heat Exchanger Influent Pump (400 gpm)	2 EA		\$5,590.00	\$11,180	

12/09/91

FILE: SERI

CH2M HILL

WASTEWATER TREATMENT FOR ETHANOL FACILITY

PROJECT NO: DEN32922.A0

PREPARED BY: E.R.MEYER

WASTEWATER TREATMENT FOR ETHANOL FACILITY

DESCRIPTION	QUANT	UNIT	\$/UNIT	TOTAL COST	REFERENCE
Primary Heat Exchanger	1	EA	\$9,046.70	\$9,047	
Nutrient Feed System	1	EA	\$23,400.00	\$23,400	
Anaerobic Reactor (2 Million Gallon)	6	EA	\$624,000.00	\$3,744,000	91 MEANS 132-051-1300 * 1.2
Biogas System	1	EA	\$144,000.00	\$144,000	
Anaerobic Mixers (20 HP)	24	EA	\$22,535.00	\$541,320	
Secondary Heat Exchanger Influent Pump	2	EA	\$5,590.00	\$11,180	
Secondary Heat Exchanger	1	EA	\$27,820.00	\$27,820	
O2 Generation & Mixing System	1	LS	\$3,600,000	\$3,600,000	
Clarifier Mechanism	2	EA	\$50,000.00	\$100,000	
RAS Pumps (400 gpm)	2	EA	\$13,840.00	\$27,680	
WAS Pumps	2	EA	\$7,800.00	\$15,600	
Mist System & Backup Carbon	1	EA	\$168,000.00	\$168,000	
Biofilter	1	EA	\$6,500.00	\$6,500	
Sludge Storage Tank (Steel, 85'D, 20'SWB, 850,000 gal)	1	EA	\$217,796.25	\$217,796	BASED ON PEARBODY TECH TANK
Storage Tank Mixers (10 HP)	4	EA	\$36,400.00	\$145,600	
Effluent Pump Station	1	EA	\$36,400.00	\$36,400	
INSTRUMENTATION					
Allowance for Instrumentation	3.00%		\$17,563,401	\$878,170	
MECHANICAL					
Allowance for Mechanical	15.00%		\$17,563,401	\$2,634,510	
ELECTRICAL					
Allowance for Electrical	10.00%		\$17,563,401	\$1,756,340	
SUBTOTAL				\$17,563,401	
CONTINGENCY	30.00%		\$17,563,401	\$5,269,020	
TOTAL - CASE 1				\$22,832,422	

NOTE: Unit costs include the cost of installation.

12/09/91

FILE: SENI

CH2M HILL

WASTEWATER TREATMENT FOR ETHANOL FACILITY

PROJECT NO: DENS2722.A0

PREPARED BY: E.R.MEYER

# WASTEWATER TREATMENT FOR ETHANOL FACILITY

DESCRIPTION	QUANT	UNIT	\$/UNIT	TOTAL COST	REFERENCE
<b>CASE 2</b>					
<b>GENERAL REQUIREMENTS:</b>					
General Requirements	6.00%		\$16,738,401	\$1,016,304	
<b>SITEWORK:</b>					
Clear & Grub	9 ACRES		\$2,000.00	\$18,000	
<b>Effluent Storage Lagoon (18 Acres):</b>					
Embankment	66,987 CY		\$10.00	\$669,867	91 MEANS 022-282-0100
HDPE Liner (20 mil)	194,564 SY		\$2.50	\$261,411	
<b>CLARIFIER STRUCTURE (20'Ø, 15' SWD):</b>					
<b>Earthwork:</b>					
Excavation	1,468 CY		\$3.00	\$3,263	
Structural Backfill	23 CY		\$10.00	\$233	
Backfill	807 CY		\$2.00	\$1,613	
<b>Concrete:</b>					
12" Slab on Grade	23 CY		\$200.00	\$4,652	
12" Walls	79 CY		\$400.00	\$31,653	
Metals:	1 LS		\$5,000.00	\$5,000	
<b>AERATION TANKS (40'X150'X17'H, ABOVE GRADE):</b>					
<b>Concrete:</b>					
12" Slab on Grade	1,111 CY		\$200.00	\$222,222	
12" Walls	1,152 CY		\$400.00	\$460,741	
Metals:	1 LS		\$5,000.00	\$5,000	
<b>BUILDINGS:</b>					
Office/Lab	2,100 SF		\$100.00	\$210,000	
Preliminary Treatment Building	900 SF		\$75.00	\$67,500	
Pump Building	1,200 SF		\$75.00	\$90,000	
Belit Filter Press Building	2,000 SF		\$75.00	\$150,000	
<b>EQUIPMENT</b>					
Bar Screens	1 EA		\$55,900.00	\$55,900	
Equalization Tank (Steel, 45'Ø, 20' SWD, 225,000 gal)	1 EA		\$126,000.00	\$126,000	91 MEANS 132-051-1000 * 1.2
Equalization Tank Mixers (3.2 HP)	3 EA		\$9,360.00	\$28,080	
Primary Heat Exchanger Influent Pump (400 gpm)	2 EA		\$5,590.00	\$11,180	



12/09/91

FILE: SERI

CH2M HILL

WASTEWATER TREATMENT FOR ETHANOL FACILITY

PROJECT NO: DENS2922.A0

PREPARED BY: E.R.MEYER

WASTEWATER TREATMENT FOR ETHANOL FACILITY

DESCRIPTION	QUANT	UNIT	\$/UNIT	TOTAL COST	REFERENCE
Primary Heat Exchanger	1	EA	\$9,046.74	\$9,047	
Nutrient Feed System	1	EA	\$23,400.00	\$23,400	
Anaerobic Reactor (2 Million Gallon)	6	EA	\$624,000.00	\$3,744,000	91 MEANS 132-051-1500 * 1.2
Biogas System	1	EA	\$144,000.00	\$144,000	
Aerobic Mixers (20' x 9')	24	EA	\$22,555.00	\$541,320	
Secondary Heat Exchanger Influent Pump	2	EA	\$5,590.00	\$11,180	
Secondary Heat Exchanger	1	EA	\$27,820.00	\$27,820	
O2 Generation & Mixing System	1	LS	\$3,200,000	\$3,200,000	
Clarifier Mechanism	2	EA	\$50,000.00	\$100,000	
WAS Pumps (400' x 10')	2	EA	\$13,850.00	\$27,700	
WAS Pumps	2	EA	\$7,800.00	\$15,600	
Mist System & Backup Carbon	1	EA	\$168,000.00	\$168,000	
Biofilter	1	EA	\$6,500.00	\$6,500	
Sludge Storage Tank (Steel, 85' D, 20' SWD, 850,000 gal)	1	EA	\$217,796.25	\$217,796	BASED ON PEARBODY TECH TANK
Storage Tank Mixers (10 HP)	4	EA	\$36,400.00	\$145,600	
Effluent Pump Station	1	EA	\$36,400.00	\$36,400	
INSTRUMENTATION					
Allowance for Instrumentation	5.00%		\$16,938,401	\$846,920	
MECHANICAL					
Allowance for Mechanical	15.00%		\$16,938,401	\$2,540,760	
ELECTRICAL					
Allowance for Electrical	10.00%		\$16,938,401	\$1,693,840	
SUBTOTAL				\$16,938,401	
CONTINGENCY	30.00%		\$16,938,401	\$5,881,520	
TOTAL - CASE 2				\$22,819,922	

NOTE: Unit costs include the cost of installation.

12/09/91

FILE: SEAT

CH2M HILL

WASTEWATER TREATMENT FOR ETHANOL FACILITY

PROJECT NO: DENG2922.A0

PREPARED BY: E.R. MEYER

WASTEWATER TREATMENT FOR ETHANOL FACILITY

DESCRIPTION	QUANT	UNIT	\$/UNIT	TOTAL COST	REFERENCE
<b>CASE 3</b>					
<b>GENERAL REQUIREMENTS:</b>					
General Requirements	1.00%		\$15,315,257	\$918,918	
<b>SITWORK:</b>					
Clear & Grub	9 ACRES		\$2,000.00	\$18,000	
Effluent Storage Lagoon (18 Acres):					
Embankment	66,987 CY		\$10.00	\$669,867	91 MEANS 022-252-0100
HDPE Liner (20 mil)	104,364 SY		\$2.50	\$261,411	
<b>CLARIFIER STRUCTURE (20'D, 15' SWD):</b>					
Earthwork:					
Excavation	1,068 CY		\$3.00	\$3,203	
Structural Backfill	23 CY		\$10.00	\$233	
Backfill	807 CY		\$2.00	\$1,613	
Concrete:					
12" Slab on Grade	23 CY		\$200.00	\$4,632	
12" Walls	79 CY		\$400.00	\$31,633	
Metals:	1 LS		\$5,000.00	\$5,000	
<b>AERATION TANKS (40'X150'X17'H, ABOVE GRADE):</b>					
Concrete:					
12" Slab on Grade	889 CY		\$200.00	\$177,778	
12" Walls	951 CY		\$400.00	\$380,393	
Metals:	1 LS		\$5,000.00	\$5,000	
<b>BUILDINGS:</b>					
Office/Lab	2,100 SF		\$100.00	\$210,000	
Preliminary Treatment Building	900 SF		\$75.00	\$67,500	
Pump Building	1,200 SF		\$75.00	\$90,000	
Wet Filter Press Building	2,000 SF		\$75.00	\$150,000	
<b>EQUIPMENT</b>					
Bar Screens	1 EA		\$55,900.00	\$55,900	
Equalization Tank (Steel, 45'D, 20' SWD, 225,000 gal)	1 EA		\$126,000.00	\$126,000	91 MEANS 132-051-1000 * 1.2
Equalization Tank Mixers (3.2 HP)	3 EA		\$9,360.00	\$28,080	
Primary Heat Exchanger Influent Pump (400 gpm)	2 EA		\$5,590.00	\$11,180	

12/09/91

FILE: 32A1

CH2M HILL

WASTEWATER TREATMENT FOR ETHANOL FACILITY

PROJECT NO: 05N32922.A0

PREPARED BY: E.R. MEYER

WASTEWATER TREATMENT FOR ETHANOL FACILITY

DESCRIPTION	QUANT	UNIT	\$/UNIT	TOTAL COST	REFERENCE
Primary Heat Exchanger	1	EA	\$9,046.70	\$9,047	
Nutrient Feed System	1	EA	\$23,400.00	\$23,400	
Anaerobic Reactor (2 Million Gallon)	5	EA	\$24,000.00	\$120,000	91 MEANS 132-051-1500 x 1.2
Biogas System	1	EA	\$144,000.00	\$144,000	
Anaerobic Mixers (20 HP)	20	EA	\$22,555.00	\$451,100	
Secondary Heat Exchanger Influent Pump	2	EA	\$5,590.00	\$11,180	
Secondary Heat Exchanger	1	EA	\$27,620.00	\$27,620	
O2 Generation & Mixing System	1	LS	\$3,000,000	\$3,000,000	
Clarifier Mechanism	2	EA	\$50,000.00	\$100,000	
RAS Pumps (400 gpm)	2	EA	\$13,840.00	\$27,680	
WAS Pumps	2	EA	\$7,800.00	\$15,600	
Mist System & Backup Carbon	1	EA	\$168,000.00	\$168,000	
Biofilter	1	EA	\$6,500.00	\$6,500	
Sludge Storage Tank (Steel, 85" D, 20' SWD, 850,000 gal)	1	EA	\$217,796.25	\$217,796	BASED ON PEARBODY TECH TANK
Storage Tank Mixers (10 HP)	4	EA	\$36,400.00	\$145,600	
Effluent Pump Station	1	EA	\$36,400.00	\$36,400	
INSTRUMENTATION					
Allowance for Instrumentation	5.00%		\$15,315,257	\$765,763	
MECHANICAL					
Allowance for Mechanical	15.00%		\$15,315,257	\$2,297,288	
ELECTRICAL					
Allowance for Electrical	10.00%		\$15,315,257	\$1,531,526	
SUBTOTAL				\$15,315,257	
CONTINGENCY	30.00%		\$15,315,257	\$4,594,577	
TOTAL - CASE 3				\$19,909,834	

NOTE: Unit costs include the cost of installation.

12/09/91

FILE: SER1

CH2M HILL

WASTEWATER TREATMENT FOR ETHANOL FACILITY

PROJECT NO: DENS2922.A0

PREPARED BY: E.R. MEYER

WASTEWATER TREATMENT FOR ETHANOL FACILITY

DESCRIPTION	QUANT	UNIT	\$/UNIT	TOTAL COST	REFERENCE
<b>CASE 4</b>					
<b>GENERAL REQUIREMENTS:</b>					
General Requirements	6.00%		\$15,315,256	\$918,913	
<b>SITWORK:</b>					
Clear & Grub	9	ACRES	\$2,000.00	\$18,000	
Effluent Storage Lagoon (18 Acres):					
Embankment	66,957	CY	\$10.00	\$669,867	91 MEANS 022-282-0100
HDPE Liner (20 mil)	104,564	SY	\$2.50	\$261,411	
<b>CLARIFIER STRUCTURE (20'D, 15' SWD):</b>					
<b>Earthwork:</b>					
Excavation	1,068	CY	\$3.00	\$3,203	
Structural Backfill	23	CY	\$10.00	\$233	
Backfill	807	CY	\$2.00	\$1,613	
<b>Concrete:</b>					
12" Slab on Grade	23	CY	\$200.00	\$4,632	
12" Walls	79	CY	\$400.00	\$31,633	
<b>Metals:</b>					
1 LB			\$5,000.00	\$5,000	
<b>AERATION TANKS (40'X150'X17'H, ABOVE GRADE):</b>					
<b>Concrete:</b>					
12" Slab on Grade	889	CY	\$200.00	\$177,778	
12" Walls	951	CY	\$400.00	\$380,593	
<b>Metals:</b>					
1 LB			\$5,000.00	\$5,000	
<b>BUILDINGS:</b>					
Office/Lab	2,100	SF	\$100.00	\$210,000	
Preliminary Treatment Building	900	SF	\$75.00	\$67,500	
Pump Building	1,200	SF	\$75.00	\$90,000	
Belt Filter Press Building	2,000	SF	\$75.00	\$150,000	
<b>EQUIPMENT</b>					
Bar Screens	1	EA	\$55,900.00	\$55,900	
Equalization Tank (Steel, 45'D, 20' SWD, 225,000 gal)	1	EA	\$126,000.00	\$126,000	91 MEANS 132-051-1000 * 1.2
Equalization Tank Mixers (3.2 HP)	3	EA	\$9,360.00	\$28,080	
Primary Heat Exchanger Influent Pump (400 gpm)	2	EA	\$5,590.00	\$11,180	

12/09/91

FILE: SERI

CH2M HILL

WASTEWATER TREATMENT FOR ETHANOL FACILITY

PROJECT NO: DENS2922.A0

PREPARED BY: E.R. MEYER

WASTEWATER TREATMENT FOR ETHANOL FACILITY

DESCRIPTION	QUANT	UNIT	\$/UNIT	TOTAL COST	REFERENCE
Primary Heat Exchanger	1	EA	\$9,046.70	\$9,047	
Nutrient Feed System	1	EA	\$23,400.00	\$23,400	
Anaerobic Reactor (2 Million Gallon)	3	EA	\$424,000.00	\$1,272,000	91 HEANS 102-051-1500 & 1.2
Biogas System	1	EA	\$144,000.00	\$144,000	
Anaerobic Mixers (20 HP)	20	EA	\$22,555.00	\$451,100	
Secondary Heat Exchanger Influent Pump	2	EA	\$5,590.00	\$11,180	
Secondary Heat Exchanger	1	EA	\$27,820.00	\$27,820	
O2 Generation & Mixing System	1	LS	\$3,000,000	\$3,000,000	
Clarifier Mechanism	2	EA	\$50,000.00	\$100,000	
RAS Pumps (400 gpm)	2	EA	\$13,840.00	\$27,680	
WAS Pumps	2	EA	\$7,800.00	\$15,600	
Mist System & Backup Carbon	1	EA	\$168,000.00	\$168,000	
Biofilter	1	EA	\$6,500.00	\$6,500	
Sludge Storage Tank (Steel, 35'D, 20'SWD, 850,000 gal)	1	EA	\$217,796.25	\$217,796	BASED ON PEARBODY TECH TANK
Storage Tank Mixers (10 HP)	4	EA	\$36,400.00	\$145,600	
Effluent Pump Station	1	EA	\$36,400.00	\$36,400	
INSTRUMENTATION					
Allowance for Instrumentation	5.00%		\$15,315,236	\$765,763	
MECHANICAL					
Allowance for Mechanical	15.00%		\$15,315,236	\$2,297,285	
ELECTRICAL					
Allowance for Electrical	10.00%		\$15,315,236	\$1,531,524	
SUBTOTAL				\$15,315,236	
CONTINGENCY	30.00%		\$15,315,236	\$4,594,577	
TOTAL - CASE 4				\$19,909,833	

NOTE: Unit costs include the cost of installation.

12/09/71

FILE: SERI

CHOW HILL

WASTEWATER TREATMENT FOR ETHANOL FACILITY

PROJECT NO: DENS2922.00

PREPARED BY: E.R.MEYER

# WASTEWATER TREATMENT FOR ETHANOL FACILITY

DESCRIPTION	QUANT	UNIT	\$/UNIT	TOTAL COST	REFERENCE
CASE 3					
GENERAL REQUIREMENTS:					
General Requirements	1.000		\$11,266,077	\$677,166	
SITEWORK:					
Clear & Grub	3	ACRES	\$2,000.00	\$16,000	
Effluent Storage Lagoon (18 Acres):					
Embankment	73,763	CY	\$10.00	\$739,627	91 MEANS 022-262-0100
HDPE Liner (20 mil)	128,741	SY	\$2.50	\$321,853	
CLARIFIER STRUCTURE (20'Ø, 15' SWD):					
Earthwork:					
Excavation	1,068	CY	\$3.00	\$3,203	
Structural Backfill	23	CY	\$10.00	\$233	
Backfill	507	CY	\$2.00	\$1,013	
Concrete:					
12" Slab on Grade	23	CY	\$200.00	\$4,632	
12" Walls	79	CY	\$400.00	\$31,633	
Metals:	1	LS	\$5,000.00	\$5,000	
AERATION TANKS (40'X150'X17'H, ABOVE GRADE):					
Concrete:					
12" Slab on Grade	667	CY	\$200.00	\$133,333	
12" Walls	751	CY	\$400.00	\$300,444	
Metals:	1	LS	\$5,000.00	\$5,000	
BUILDINGS:					
Office/Lab	2,100	SF	\$100.00	\$210,000	
Preliminary Treatment Building	900	SF	\$75.00	\$67,500	
Pump Building	1,200	SF	\$75.00	\$90,000	
Salt Filter Press Building	2,000	SF	\$75.00	\$150,000	
EQUIPMENT					
Bar Screens	1	EA	\$55,900.00	\$55,900	
Equalization Tank (Steel, 45'Ø, 20' SWD, 225,000 gal)	1	EA	\$126,000.00	\$126,000	91 MEANS 132-031-1000 * 1.2
Equalization Tank Mixers (3.2 HP)	3	EA	\$8,330.00	\$25,000	
Primary Heat Exchanger Influent Pump (400 gpm)	2	EA	\$5,550.00	\$11,100	

12/09/91

FILE: 6821

CHEN HILL

WASTEWATER TREATMENT FOR ETHANOL FACILITY

PROJECT NO: DENV0222.A0

PREPARED BY: E.R. REVER

WASTEWATER TREATMENT FOR ETHANOL FACILITY

DESCRIPTION	QUANT	UNIT	\$/UNIT	TOTAL COST	REFERENCE
Primary Heat Exchanger	1	EA	\$9,546.79	\$9,547	
Nutrient Feed System	1	EA	\$23,400.00	\$23,400	
Anaerobic Reactor (2 Million Gallon)	3	EA	\$624,000.00	\$1,872,000	PI MEANS 132-031-1500 = 1.2
Biogas System	1	EA	\$144,000.00	\$144,000	
Anerobic Mixers (20 HP)	12	EA	\$22,555.00	\$270,660	
Secondary Heat Exchanger Influent Pump	2	EA	\$5,590.00	\$11,180	
Secondary Heat Exchanger	1	EA	\$27,520.00	\$27,520	
O2 Generation & Mixing System	1	LS	\$1,800,000	\$1,800,000	
Clarifier Mechanies	2	EA	\$50,000.00	\$100,000	
RAS Pumps (400 gpm)	2	EA	\$13,340.00	\$27,680	
WAS Pumps	2	EA	\$7,300.00	\$14,600	
Mist System & Backup Carbon	1	EA	\$160,000.00	\$160,000	
Biofilter	1	EA	\$6,500.00	\$6,500	
Sludge Storage Tank (Steel, 85'x20'SWD, 850,000 gal)	1	EA	\$217,796.23	\$217,796	BASED ON PEARBODY TECH TANK
Storage Tank Mixers (10 HP)	4	EA	\$36,400.00	\$145,600	
Effluent Pump Station	1	EA	\$36,400.00	\$36,400	
INSTRUMENTATION					
Allowance for Instrumentation	5.00%		\$11,286,077	\$564,303	
MECHANICAL					
Allowance for Mechanical	15.00%		\$11,286,077	\$1,652,914	
ELECTRICAL					
Allowance for Electrical	10.00%		\$11,286,077	\$1,128,610	
SUBTOTAL				\$11,286,077	
CONTINGENCY	30.00%		\$11,286,077	\$3,385,829	
TOTAL - CASE 5				\$14,671,925	

NOTE: Unit costs include the cost of installation.

SERI O&M COST TABLE  
 FILE SERI\_O&M.WK1  
 CDW, 12-3-91, DEN32922.A0

THE FOLLOWING TABULATED O&M COSTS PROJECTED FOR THE SERI WWTP  
 ESTIMATES ARE CONSERVATIVE. NUMBERS ARE BASED ON VENDOR SUPPLIED  
 POWER REQUIREMENTS PROVIDED FOR CONCEPTUAL DESIGN EQUIPMENT. THESE ARE 1991 DOLLARS.

# POWER COSTS

CALC :  $\text{HP} \times 24 \text{ HR/DAY} \times .7457 \text{ KWHR/HPHR} \times \text{P\$/KWHR} = \text{\$/DAY}$   
 ( note : Albuquerque, NM power costs used for this application)  
 ASSUME P = \$0.04 PER KWHR

## CASE

### EQUIPMENT

ITEM	1		2		3		4		5		6	
	hp	\$/day	hp	\$/day	hp	\$/day	hp	\$/day	hp	\$/day	hp	\$/day
Bar Screens	0.5	\$0.36	0.5	0.6	0.5	0.6	0.5	0.6	0.5	0.6	0.5	0.6
Equalization mixer	12.0	\$8.59	12.0	15.0	12.0	15.0	12.0	15.0	12.0	15.0	12.0	15.0
Primary Pump	5.0	\$3.58	5.0	6.2	5.0	6.2	5.0	6.2	5.0	6.2	5.0	6.2
Nutrient Mixing	0.5	\$0.36	0.5	\$0.36	0.5	\$0.36	0.5	\$0.36	0.5	\$0.36	0.5	\$0.36
Nutrient pumping	0.5	\$0.36	0.5	\$0.36	0.5	\$0.36	0.5	\$0.36	0.5	\$0.36	0.5	\$0.36
Anaerobic mixer	480.0	\$343.62	480.0	\$343.62	400.0	\$286.35	400.0	\$286.35	240.0	\$171.81	240.0	\$171.81
Secondary Pump	5.0	\$3.58	5.0	\$3.58	5.0	\$3.58	5.0	\$3.58	5.0	\$3.58	5.0	\$3.58
O2 Mixing	300.0	\$214.76	300.0	\$214.76	240.0	\$171.81	240.0	\$171.81	180.0	\$128.86	120.0	\$85.90
O2 Generation	540.0	\$386.67	480.0	\$343.62	450.0	\$322.14	450.0	\$322.14	270.0	\$183.29	240.0	\$171.81
RAS Pumping	3.0	\$2.15	3.0	\$2.15	3.0	\$2.15	3.0	\$2.15	3.0	\$2.15	3.0	\$2.15
WAS Pumping	2.0	\$1.43	2.0	\$1.43	2.0	\$1.43	2.0	\$1.43	2.0	\$1.43	2.0	\$1.43
Sludge Mixing	40.0	\$28.63	40.0	\$28.63	40.0	\$28.63	40.0	\$28.63	40.0	\$28.63	0.0	\$0.00
Belt Filter Press	0.0	\$0.00	0.0	\$0.00	0.0	\$0.00	0.0	\$0.00	0.0	\$0.00	10.0	\$7.16
Filtrate Pumping	0.0	\$0.00	0.0	\$0.00	0.0	\$0.00	0.0	\$0.00	0.0	\$0.00	5.0	\$3.58
Eff. Recycle Pump	5.0	\$3.58	5.0	\$3.58	5.0	\$3.58	5.0	\$3.58	5.0	\$3.58	0.0	\$0.00
Scrubber Supply Fan	5.0	\$3.58	5.0	\$3.58	5.0	\$3.58	5.0	\$3.58	5.0	\$3.58	5.0	\$3.58
Scrubber Exhaust Fan	0.0	\$0.00	0.0	\$0.00	0.0	\$0.00	0.0	\$0.00	0.0	\$0.00	16.0	\$11.45
Polymer Pumping	0.0	\$0.00	0.0	\$0.00	0.0	\$0.00	0.0	\$0.00	0.0	\$0.00	0.5	\$0.36
Effluent Pumping	5.0	\$3.58	5.0	\$3.58	5.0	\$3.58	5.0	\$3.58	5.0	\$3.58	0.0	\$0.00
total :	1403.5	\$1,004.73	1343.5	\$971.08	1173.5	\$849.38	1173.5	\$849.38	773.5	\$583.03	665.0	\$485.36
Lights & HVAC @ %10:	140.4	\$100.47	134.4	\$97.11	117.4	\$84.94	117.4	\$84.94	77.4	\$56.30	66.5	\$48.54



Total per day:	1543.85	\$1,105.20	1477.85	\$1,088.18	1290.85	\$934.32	1290.85	\$934.32	850.85	\$619.33	731.5	\$533.89
Total per year :	563505.25	\$403,397.63	539415.25	\$389,886.97	471180.25	\$341,025.13	471180.25	\$341,025.13	310580.25	\$228,056.08	266997.5	\$194,870.73

#### INPUT COSTS

#### CASE

		1		2		3		4		5		6	
UNIT CO	UNIT INPUT	AMOUNT	\$/DAY	AMOUNT	\$/DAY	AMOUNT	\$/DAY	AMOUNT	\$/DAY	AMOUNT	\$/DAY	AMOUNT	\$/DAY
\$0.14	UREA, lb/d	8400	\$1,142.40	7800	\$1,080.80	7450	\$1,013.20	7300	\$992.80	4400	\$598.40	3700	\$503.20
\$0.38	TRIPLE S PHOS., lb/d	3300	\$1,267.20	3000	\$1,152.00	2900	\$1,113.60	2800	\$1,075.20	1700	\$652.80	1500	\$576.00
\$12.00	POTABLE H2O, M lb/d	7.6	\$91.37	7.8	\$91.37	7.6	\$91.37	7.8	\$91.37	6.7	\$88.57	6.7	\$88.57
\$0.01	MANURE, lb/d	83.8	\$0.84	77.8	\$0.78	74.5	\$0.75	72.8	\$0.73	44.3	\$0.44	0	\$0.00
\$1.00	%50 CAUSTIC, gal/d	0	\$0.00	0	\$0.00	0	\$0.00	0	\$0.00	0	\$0.00	1.2	\$1.20
\$4.30	GAC REPL., lb/d	0	\$0.00	0	\$0.00	0	\$0.00	0	\$0.00	0	\$0.00	3.21	\$13.80
\$1.40	POLYMER, lb/d	0	\$0.00	0	\$0.00	0	\$0.00	0	\$0.00	0	\$0.00	31.8	\$44.52
	SLUDGE APPL., lb/d	14200	\$0.00	13200	\$0.00	12700	\$0.00	12400	\$0.00	7580	\$0.00	0	\$0.00
\$900.00	POTW DISCHARGE, M	0	\$0.00	0	\$0.00	0	\$0.00	0	\$0.00	0	\$0.00	0.8	\$540.00

TOTAL PER DAY :	\$2,501.81	\$2,304.95	\$2,218.92	\$2,160.10	\$1,320.22	\$1,747.30
TOTAL PER YEAR :	\$913,161.02	\$841,307.12	\$808,905.07	\$788,436.87	\$481,878.84	\$637,763.04

#### LABOR COSTS

#### UNIT COST

\$43,210	LABOR	3	\$129,630.00	3	\$129,630.00	3	\$129,630.00	3	\$129,630.00	3	\$129,630.00	3	\$129,630.00
\$49,300	FOREMAN	1	\$49,300.00	1	\$49,300.00	1	\$49,300.00	1	\$49,300.00	1	\$49,300.00	1	\$49,300.00
\$58,000	SUPERVISOR	1	\$58,000.00	1	\$58,000.00	1	\$58,000.00	1	\$58,000.00	1	\$58,000.00	1	\$58,000.00

TOTAL PER YEAR:	\$238,930.00	\$238,930.00	\$238,930.00	\$238,930.00	\$238,930.00	\$238,930.00
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#### MAINTENANCE COST

3.00% OF CAPITAL	\$22,832,000	\$684,960	\$22,020,000	\$660,600	\$19,910,000	\$597,300	\$19,910,000	\$597,300	\$14,672,000	\$440,160	\$11,390,000	\$341,700
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**GENERAL PLANT OVERHEAD**

65% OF LABOR AND MAINT    \$921,890    \$599,229    \$897,530    \$583,395    \$834,230    \$542,260    \$834,230    \$542,260    \$677,090    \$440,109    \$578,630    \$376,110

**CASE**

	1		2		3		4		5		6	
SUBTOTAL		\$2,837,677		\$2,712,119		\$2,627,410		\$2,505,941		\$1,825,133		\$1,787,373
SCOPE CONTINGENCY	10%	\$283,768	10%	\$271,212	10%	\$262,741	10%	\$250,594	10%	\$182,513	10%	\$178,737
TOTAL ANNUAL O&M COST		\$3,121,445		\$2,983,330		\$2,780,151		\$2,756,536		\$2,007,647		\$1,966,111

## **COST ESTIMATE ASSUMPTIONS**

### **CAPITAL COST ESTIMATES**

- Land application equipment will be provided as part of the crop production system.
- Cost of land is not included.
- The wastewater system is in the vicinity of the production facility and the point of discharge, so that extreme piping lengths are not required to get the wastewater to the plant and to get the effluent to the point of discharge.
- Special materials of construction are not required.
- A relatively inexpensive liner may be used for the effluent storage lagoons since the effluent is relatively benign.

### **OPERATIONS AND MAINTENANCE COST ESTIMATES**

- Maximum power consumptions were used for each piece of equipment, so that the power costs are conservative.
- The operations costs include a "general plant overhead" allowance, as described by NREL.
- The cost of disposal of ash from the sludge burned in the boiler in Case 6 is not significant.
- No credit is taken for the methane burned in the boiler.
- Five operators are required to operate the facility and to perform laboratory analysis.
- The cost of sludge and effluent land application is covered in the cost of crop production.
- The oxygen used in the sludge storage tank is insignificant.